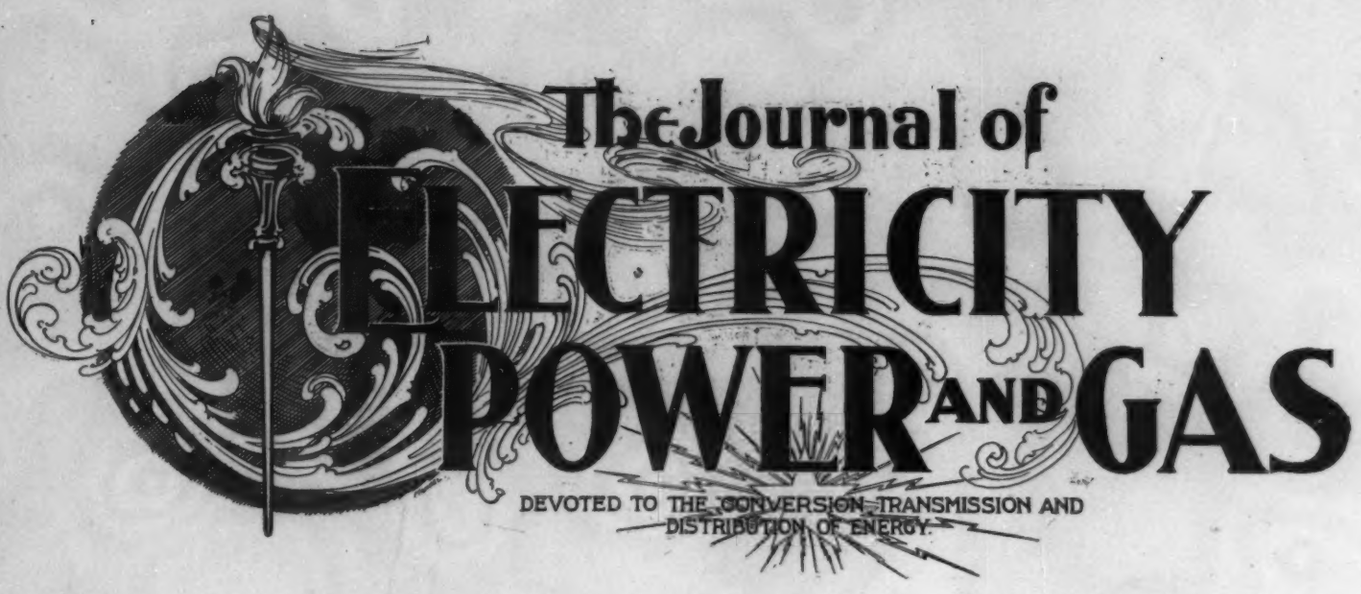


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1899

Transmission Association Convention

# The Journal of ELECTRICITY POWER AND GAS

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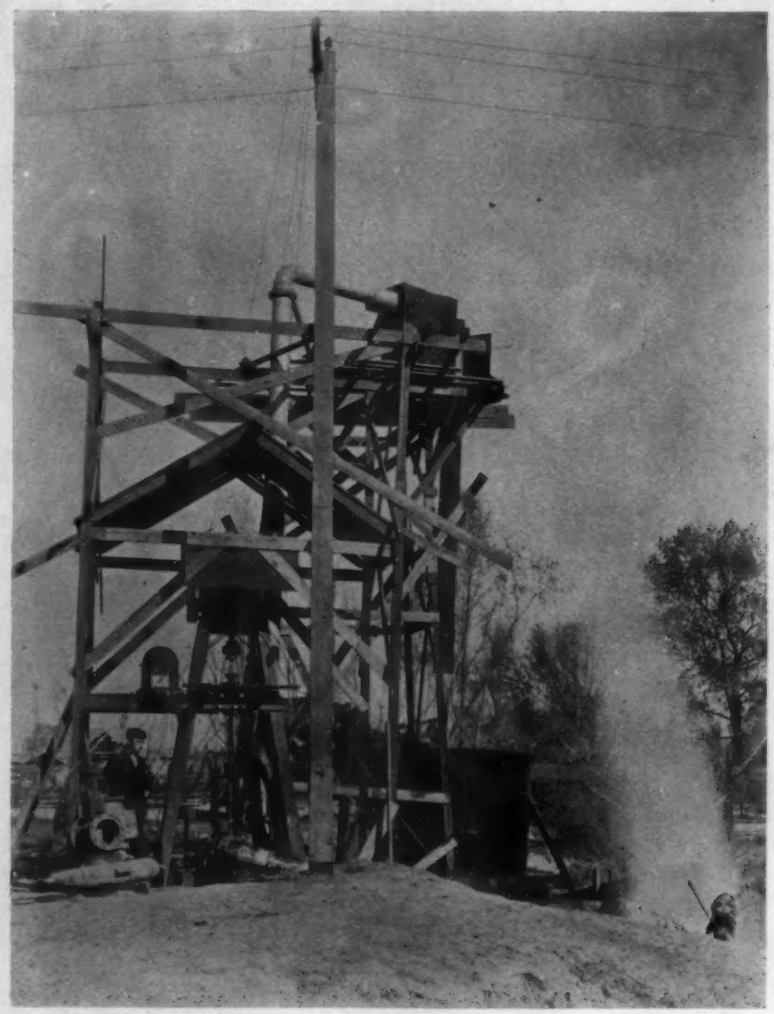
VOLUME VIII. SAN FRANCISCO, JULY, 1899. NUMBER 1.

# *Electrically-Driven Centrifugal Pumps.**

*BY LEWIS A. HICKS, C. E.*

THE drought of the past two years in California has been productive of great expansion in the manufacture of pumps suitable for irrigation purposes, and the contemporaneous development of numerous projects for the electrical transmission of water power, at such intensities that distance comes to be of decreasing importance, is favorable to the continued utilization of pumping as a means of supplying water for irrigated land, insuring crops in dry years, and so maintaining land values and load factors.

The Kern County Land Co., through whose courtesy the writer is permitted to present the experiments hereafter described, has engaged in the pumping business on a scale of considerable magnitude, involving the use of some 600 or 700 horsepower, inclusive of the plants now in use, in course of construction, and in contemplation. The plants as first installed consisted of four wells, of 13-inch perforated casing to a depth of 70 to 80 feet, connected by common suction pipes to a No. 12 centrifugal pump set on the floor of a pit 8 to 12 feet deep, the average depth to the standing level of well water. The pumps were belted to 30-horsepower induction motors, actuated by three-phase current purchased from the Power Development Company, and when in operation draw the water down in the wells to a depth of 20 feet, making a total lift of 28 to 34 feet, and deliver a flow of three to four cubic feet per second. Several stations a mile or more apart are operated by one attendant, not a mechanic, and the heavy belts and hot bearings soon proved a source of annoyance and expense, which led to the consideration of coupling the pump direct to the motor. During wet years, or periods of heavy irrigation in the vicinity of pumping stations, the water level rises to a point that would submerge the band wheel of the pump, while in periods of extreme drought it may fall below suction depth. The natural relief from these difficulties was to resort to the use of vertical shaft pumps, direct-coupled to vertical shaft motors, a plan which would make it possible to set the pumps as deep as might seem desirable, regardless of the height of the water line, while retaining the motor on the surface out of danger.



TESTING AN ELECTRICALLY-DRIVEN CENTRIFUGAL PUMP.

Such motors were not on the market at that time, but it was felt that the advantages gained by such an assembly

*A paper read before the Third Annual Convention of the Pacific Coast Electric Transmission Association, San Francisco, June 20-21, 1899.

would justify the development of suitable motors if it proved possible to construct a pump which would give a satisfactory efficiency under the proposed conditions; *viz.*: inlet and outlet areas ten inches in diameter and a capacity of five cubic feet per second when operating at 900 revolutions per minute against a total lift of 30 feet.

As ordinarily constructed, the relation between the peripheral runner speed and the height of lift is expressed by the formula

$$d \times \pi \times \text{R. P. M.} = 60 \times 10\sqrt{h}$$

where d = the diameter of the runner and h the height of the lift, both in feet. In any given pump the expression $d \times \pi$ is, of course, a constant, and the speed varies with the square root of the head. Applying this formula to the case under consideration to obtain a suitable runner diameter for a constant speed of 900 revolutions per minute, we find that the resulting value of d is but little in excess of the specified area of the suction inlet and there would consequently be no room for the working vanes. Increasing the diameter of the runner to allow for the

THE INDUCTION MOTOR WAS MOUNTED VERTICALLY.

vanes necessarily increases the peripheral speed beyond ordinary limits. The question was submitted to several of the leading manufacturers of centrifugal pumps on the Coast without eliciting any marked desire on their part to undertake the problem otherwise than as an experiment at our expense, without any guarantee as to results, it being the commonly expressed idea that the high peripheral speed of the impeller would decrease the efficiency of the pump below the limit set.

Byron Jackson, a well-known pump manufacturer of San Francisco, was the only person who squarely accepted the specification that the manufacturer must guarantee a pump efficiency of 50 per cent., the lift to be calculated from the sum of the static and frictional resistances as indicated by gages on suction and discharge pipes, failing in which the pumps were to remain the property of the contractor.

For the purpose of this experiment it was decided to use a standard General Electric 30-horsepower, 550-volt induction motor of the compensator type, turned over on its side, supported on the stud bolts which fasten the side shields to the field frame, and coupled direct to the pump shaft with ordinary flange couplings. As the correctness of the results might be called in question by the contractor in the event of our refusing to accept the pump, it was thought best to determine the characteristic curves of the motor to be used in testing the pump by means of absorption dynamometer tests. The friction brake was of the usual Prony type, eight inches in width, with a lever arm 3½ feet long, from the end of which the resultant was delivered by a reducing lever with a three-to-one reduction to a spring balance graduated to read to single ounces, giving a brake arm in effect 10½ feet in length, and modifying the ordinary brake formula to the following:

$$\text{HP.} = .002 \times \text{R. P. M.} \times \text{scale reading.}$$

The brake blocks and lever arm were balanced in place on knife edges, and were used on a 13-inch cast iron pulley, the crown of which had been turned off flat the width of the brake blocks. The pulley was so arranged that it could be cooled from the inside with water, and it was found that the motor could be held at any desired output for a considerable interval without undue heating. The extreme range of the pointer on the spring balance during the weighing of a given output never exceeded eight ounces, and it is believed that the error in reading the mean or average of such variations could not exceed two ounces, representing a maximum error of one-quarter of a horsepower in the determination of the mechanical output. The electrical input was measured in the usual way, the testing equipment consisting of

One 7½-kilowatt Weston wattmeter, connected through a multiplying Y-box with a ratio of 5 to 1;

One Thomson inclined coil 600-volt voltmeter;

One Thomson 200-ampere ammeter, and a

40-ampere Thomson switchboard ammeter, together with a portable tachometer.

All of these instruments had been recently calibrated with standard instruments and were believed to be correct. Whether this is so or not in an absolute sense was immaterial for the purpose in hand, since the instruments themselves were rated for known loads through the friction brake, and when used to determine the electrical input must indicate, under similar line conditions, the same ratio between input and output. A special switchboard was designed for these tests, each leg having a separate knife switch with a by-pass plug connection, so arranged that the wattmeter and ammeter could be cut in series on either leg, and successive readings from the three legs could be obtained in thirty seconds, the connections to the voltmeter being shifted at the same time. Four observers took the records, one at the brake, one with the tachometer, one for the volt and ammeters, and one for the wattmeter. Readings were repeated on each leg to avoid errors. The special arrangement for securing accurate electrical data was devised by Mr. Frank T. Whorff, superintendent for the Power Development Company, who, with his assistant, Mr. George Correa, made and recorded all the electrical measurements taken.

The resulting curves for efficiency and power factor are

shown in Figure 1. If the tests had been made with a transmission dynamometer after continuous operation of the motor, until the full heating effect had been developed, the efficiency curve would probably fall off somewhat from the results shown under test conditions, with the motor practically cold; but as the pump tests were only a few minutes in duration, the condition of the motor was practically the same as when under test, and the curve correctly represents the output for similar conditions within the limits of error indicated by the observations themselves.

Four runners were delivered to us by the contractor for testing, all of the enclosed type, 18 inches in diameter, with vanes and waterways designed to suit the contractor's ideas of the changes from ordinary practice essential to successfully meet the new conditions. The vane curves and other dimensions are shown in Figure 2. Two of the runners were made with 10-inch suction inlets for use in a standard No. 10 shell, which, as ordinarily used, is equipped with a 24-inch runner. Ports were cut through the runner from the suction side into a balance ring, cast in the bottom plate of the pump, to partly equalize the disproportion of area exposed to discharge pressure on the upper and lower side of the runner, but leaving by construction an unbalanced excess of upward pressure, which in operation proved to be downward. The other pair of runners were cast with 8-inch inlets without balance rings and intended to have the same degree of curvature, but through inadvertance were given slightly larger waterways than the No. 10 runners. An 8-inch shell was provided for these runners with a close-fitting joint between the throat of the pump and periphery of runner, which made it possible to alter the thrust by raising or lowering the runner, the small, unbalanced resultant, either up or down, being carried on collars working against balls running in oil in a vertical thrust bearing. When starting, the entire weight of the rotor, shafting, runner, and couplings rested on the ball bearings, but as soon as discharge pressure was obtained most of this weight was counterbalanced by the upthrust of the runner.

The pumps were set up on the bank of the Kern Island Canal, and were connected with double 10-inch suction and a 10-inch discharge pipe which delivered the water horizontally into a deflecting box shaped like the letter Y, with a hinged gate operating through an acute angle and opening and closing either outlet simultaneously. One outlet connected into a galvanized iron measuring tank, and the other allowed the discharge to waste back into the stream. The gate could be operated in a fraction of a second in admitting water to the tank. Time was taken with a stop-watch reading to one-fifth of a second, and the accuracy of the apparatus is indicated by the fact that in four successive measurements of the same flowage the variation in time was only two-fifths of a second in 42 seconds, or something less than one per cent.

The static lift was measured direct from the surface of the water to the center of the horizontal discharge pipe, and the sum of the static and friction resistances was obtained from the readings of a pressure gage on the discharge pipe above the outlet elbow graduated to single pounds and a vacuum gage on the suction pipe graduated to inches. These gages were tested and found correct immediately before being used and the proper correction for relative vertical position was made. The same switch-

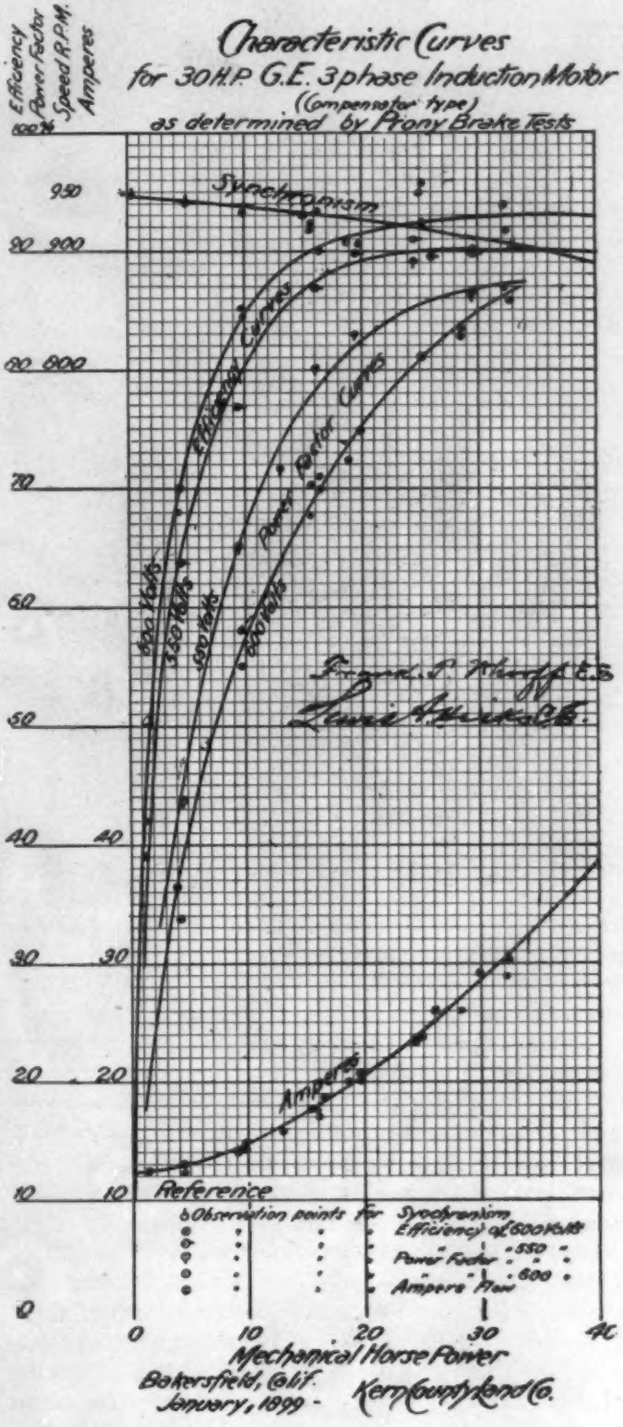



FIGURE 1.—HICKS ON CENTRIFUGAL PUMPS.

board and electrical instruments were used in the pump tests that have already been described in connection with the motor tests, and the motor was the same one that had been subjected to brake tests. The setting of the pump

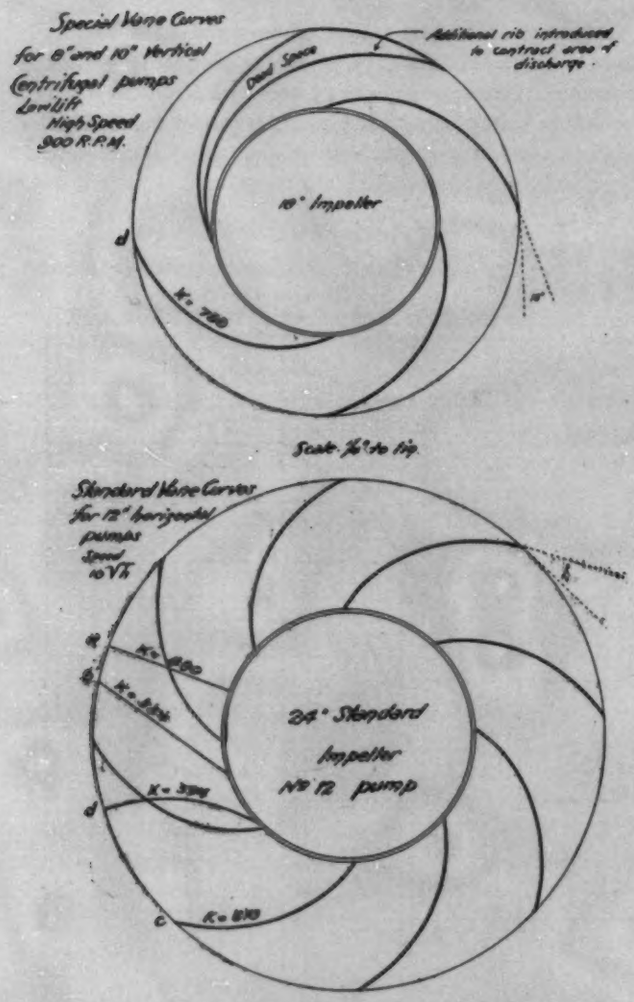



FIGURE 2.—HICKS ON CENTRIFUGAL PUMPS.

and motor together with the arrangements for measuring the discharge will be understood from the accompanying photographs. The observed data and calculations resulting therefrom are given in the accompanying tabulations which are believed to be self-explanatory. There is included in this tabulation the test of two horizontal shaft centrifugal pumps belted to induction motors, which may be taken as representative of the results obtained in previous installations. The motors were of the same type and output as the one for which curves are given, and the testing apparatus was identical, except that a measuring weir was used to determine the discharge in place of a tank. The weir was built with a thin iron lip to conform to the Francis experiments, and the coefficients derived from those experiments for flow without end contractions were used to calculate the discharge. It will be seen from the efficiencies shown that the contractor was entirely successful in his undertaking, but the marked improvement over the No. 12 pump with ordinary commercial runner is largely due to the disproportionate size of the pump with reference to available water supply. The insufficient water supply also led to the throttling of the discharge pipe to balance the runner, and, as will be seen from the column, "discharge-pipe friction," this one item probably amounted to ten per cent. of the expended energy. The belt-friction load probably amounted to another horsepower. Allowing for these resistances, the writer has reason to believe that the net efficiency of the standard runners when pumping their rated capacity is substantially the same as the special runners.

Granting that any centrifugal pump, with enclosed runner, may be adapted to high-speed work by suitable alterations of the runner, considerations of convenience and compactness in setting and operation, as well as economy in deterioration of belts and bearings, settles the question in favor of the vertical form, and, as a result of these tests, contracts have been made for the manufacture of eight such pumps and vertical shaft motors, to be installed by the Kern County Land Company.

There is another outlet for power consumption by centrifugal pumps, which in Bakersfield, we owe to Mr W. L. Dixon, engineer for the Electric Water Company. This company made its installation under his advice and now pump the entire domestic water supply of Bakersfield with two No. 4 centrifugal pumps direct-connected to induction motors. These pumps are situated about half a mile apart and discharge directly into six-inch mains without any connection to a stand pipe or tank, and maintain a hydrostatic pressure of 30 to 45 pounds in the mains. As originally installed, one of these pumps discharged

Calculated Results - Test of No 4 Centrifugal pump - Electric Water Co.

| No | Equivalent Heads Feet | | | Friction Heads Feet | | | | | | Discharge | | Velocity Suction and Discharge | Velocity Pump Outlet & Stuffing | C | Water Horse Power | Water Efficiency % | Motor Horse Power | Pump | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Discharge | Suction | Total W.P. | Discharge pipe | Suction pipe | Discharge Elbows | Suction Elbow and Foot Valve | Velocity and Entrance Head | Weir | Total | Cu. ft. per second | Gallons per minute | | | | | | Water Horse Power | Water Efficiency Pump |
| 1 | 115.33 | 4.50 | 119.83 | | | | | | | | | | ft. per Second | ft. per Second | 24.00 | 69 | 22.10 | 0.00 | % | % |
| 2 | 104.12 | 11.33 | 115.75 | 0.63 | 0.12 | 0.42 | 1.70 | 0.18 | 96.69 | 99.72 | 2.21 | 209 | 2.30 | 5.2 | .14 | 27.11 | 69½ | 24.12 | 5.94 | 24.63 | 52 |
| 3 | 98.42 | 13.83 | 112.25 | 5.75 | 0.53 | 1.25 | 2.12 | 0.30 | 83.12 | 93.22 | 4.15 | 389 | 3.95 | 8.9 | .16 | 30.13 | 90 | 26.97 | 9.62 | 35.67 | 75 |
| 4 | 69.00 | 18.92 | 87.92 | 3.30 | 0.68 | 2.33 | 2.36 | 1.00 | 69.00 | 78.67 | 6.80 | 634 | 5.61 | 12.7 | .16 | 33.53 | 90 | 30.23 | 12.86 | 42.54 | 69 |
| 5 | 70.42 | 27.16 | 97.58 | 5.00 | 1.00 | 3.38 | 5.31 | 1.52 | 58.69 | 74.91 | 8.25 | 617 | 7.01 | 15.0 | .18 | 35.71 | 90 | 32.13 | 15.25 | 47.38 | 100 |
| 6 | 59.08 | 31.70 | 90.78 | 5.70 | 1.14 | 4.15 | 7.55 | 1.76 | 41.83 | 62.13 | 8.24 | 669 | 7.60 | 17.1 | .17 | 38.58 | 90 | 34.76 | 15.35 | 44.34 | 94 |
| 7 | 47.39 | 31.70 | 79.09 | 6.00 | 1.20 | 4.42 | 7.84 | 1.84 | 29.62 | 50.32 | 9.1 | 682 | 7.74 | 17.4 | .15 | 37.11 | 90 | 33.40 | 13.64 | 40.84 | 86 |
| 8 | 35.92 | 31.70 | 67.62 | 6.00 | 1.20 | 4.42 | 7.84 | 1.83 | 17.92 | 39.13 | 9.1 | 682 | 7.74 | 17.4 | .13 | 35.51 | 90 | 31.95 | 11.67 | 36.47 | 77 |
| 9 | 24.42 | 31.70 | 56.12 | 6.10 | 1.22 | 4.49 | 7.96 | 1.86 | 6.50 | 28.25 | 9.14 | 684 | 7.77 | 17.5 | .12 | 33.22 | 90 | 29.90 | 9.71 | 32.47 | 69 |
| 10 | 17.62 | 32.63 | 50.25 | 5.90 | 1.18 | 4.30 | 8.10 | 1.90 | 0.00 | 21.28 | 9.06 | 678 | 7.70 | 17.3 | .11 | 31.70 | 90 | 28.53 | 8.62 | 30.21 | 63 |
| 11 | 57.75 | 30.58 | 88.33 | 7.75 | 1.08 | 4.20 | 6.87 | 1.50 | 0.00 | 19.39 | 9.05 | 678 | 7.70 | 17.3 | .16 | 37.79 | 90 | 34.01 | 15.16 | 46.54 | 94 |
| 12 | 37.92 | 30.58 | 68.50 | 7.50 | 1.08 | 4.16 | 6.91 | 1.76 | 0.00 | 17.50 | 9.03 | 667 | 7.60 | 17.2 | .13 | 35.91 | 90 | 32.32 | 11.58 | 35.83 | 76 |

Calculated Results of Tests made Sept 6th 1910
* Calculated for discharge pipe area and velocity $c = \frac{D}{1.1\sqrt{Hp}}$
Note - As Electric measurements were only made on one leg, efficiencies are probably in error, but relative efficiencies would be about correct, assuming maximum efficiency realized as 100%. Assuming the correctness of efficiencies as shown, the delivery into mains at working pressures ranges from 100 to 130 thousand kilogallons per K.W. hour.
Louis A. Hicks, C.E.

FIGURE 3.—HICKS ON CENTRIFUGAL PUMPS.

into a 50,000-gallon tank at an elevation of 70 feet, from which the city supply was drawn by gravity. But it was soon found that better service was secured by pumping directly into the main, and at present the tanks are only

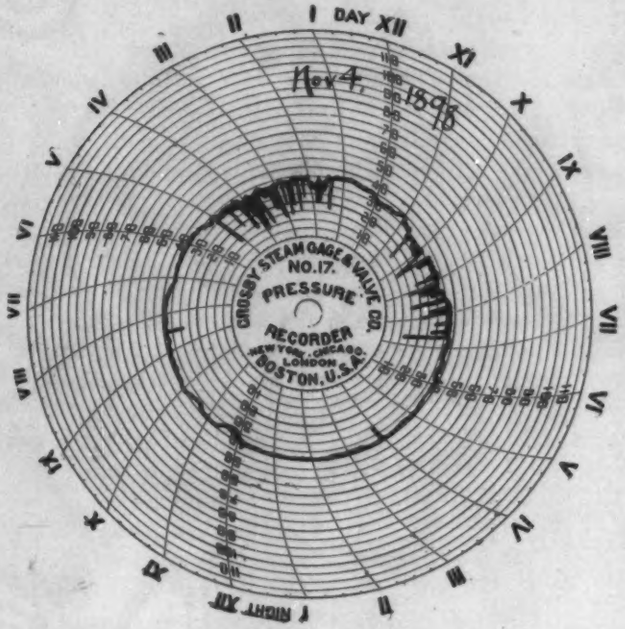



FIGURE 4.—HICKS ON CENTRIFUGAL PUMPS.

used for reserves in case of temporary shut down of the power.

The local flour mill has been operated for some years past by means of a turbine, taking water from a gravity canal. This wheel has been connected up to a motor-generator, which, in case of accident, is run as a generator supplying current to the city pumps, or in case the water is diverted into other canals it takes current from the lines of the Power Development Company and drives the mill. This constitutes the main reserve. The pumps regulate themselves, delivering under a remarkably steady pressure whatever quantity is called for by the draft on the pipes. If the draft increases, the volume pumped automatically increases as the pressure decreases, and if the draft were to cease entirely, by the closing of all cocks the only effect at the pump would be to slightly increase the pressure. Figures 4 and 5 are sample sheets from the daily record of an automatic gage on one of the pumps, showing the normal working variations in pressure. The sudden fall in pressure for a small time interval, making almost a straight line on the diagram, represents the opening of a three-inch valve to supply city sprinkling carts.

Certain interesting facts develop in connection with the operation of these pumps.

It was pointed out to the writer about a year ago by Mr. Edward S. Cobb, of San Francisco, that for constant speed the discharge of a centrifugal pump for any lift varies with the square root of the difference between the actual lift and the hydrostatic head created by the pump without discharge. If any centrifugal pump connected to a source of supply and to a discharge pipe of considerable height is put in revolution, it will be found that it is necessary to maintain a certain peripheral runner speed to hold the water one foot high without discharge, and that for any other height the requisite speed will be very nearly as the square of the velocity for one foot. One of our most reliable mechanical hand-books states that the peripheral runner velocity in feet per minute required to hold water to any height without discharge is equal to 500 $\sqrt{h}$, basing the statement on experiments with the Appold pump, and making no qualfication whatever as to the form of the vane, but treating the matter as though the constant 500 is suitable for any and all centrifugal pumps.

Other experiments prove, however, that the speed necessary to lift water to a given height with vanes of the form shown in diagram No. 8 is approximately as follows:

| | |
|---|---|
| *a* | 481 $\sqrt{h}$ |
| *b* | 554 $\sqrt{h}$ |
| *c* | 610 $\sqrt{h}$ |
| *d* | 780 $\sqrt{h}$ |
| *e* | 394 $\sqrt{h}$ |

It appears then, that instead of being a constant for all pumps, this number varies with the shape of the vanes, and as this means that different speeds are necessary to hold water to the same heights with these different forms of vanes, it follows that for any constant speed or lift there must be a form of vane more suitable than any other. It would seem at first glance that the runner which creates a given hydrostatic head with the least peripheral velocity must be the most efficient, but practically it is apparent from the tests heretofore described that the

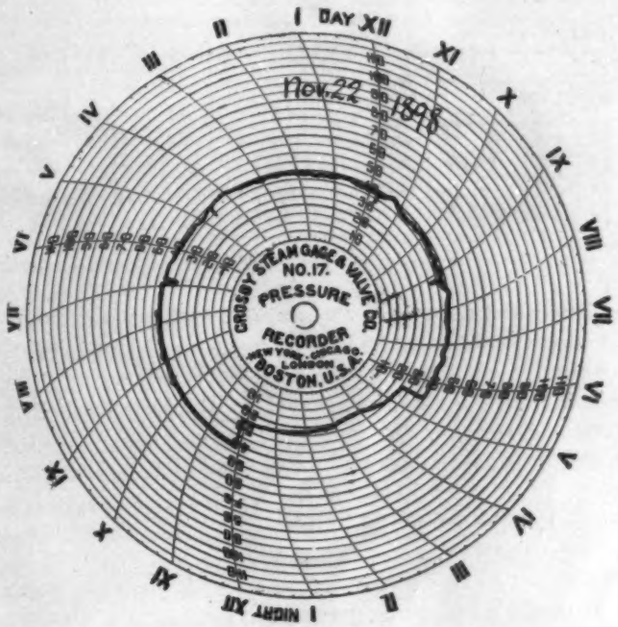



FIGURE 5.—HICKS ON CENTRIFUGAL PUMPS

curvature of the vanes can be designed to suit the speed and lift without materially lowering the efficiency.

Consider any horizontal shaft centrifugal pump so connected to a source of supply that the level of the water would be maintained at the top of the runner, and provi-

ded with a vertical discharge pipe of greater height than the hydrostatic head which the pump can create at the speed at which it is to be operated, and of relatively larger diameter than the pump outlet. Let K = the peripheral speed per minute necessary to raise water one foot without discharge with the form of vane used, and V any other peripheral speed per minute; then the height H, at which water will be held without flow in the discharge pipe, will be represented by the expression

$$H = \frac{V^2}{K^2}$$ Figure 8.

Now suppose an opening relatively small as compared to the diameter of the pump outlet to be made at a distance h below the level where the water is held. It is evident that following the well-known laws of flow through orifices, discharge will take place in proportion to the square root of $h - h_2$, multiplied into suitable coefficient of

Data of Tests

| No | Size of Pump | Connection | Impeller | R.P.M. Motor | R.P.M. Pump | Static Lift Suction | Static Lift Disch. | Static Lift Total | Gages Vacuum | Gages Pressure | Gages Distance Between Gages | Electric Leg | Electric Volts | Electric Amps | Electric Watts | Discharge Time | Discharge Tank | Discharge Gallons | Discharge Weir | Discharge Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | No. 10 Vertical | Direct | 10" Inclosed Open * | 945 | 945 | Ft. 7.19 | Ft. 24.03 | Ft. 31.21 | Inches .9 | Lbs 12 | Ft. -.13 | A | 550 | 37½ | 10425 | Seconds | Gallons | | | Gallons |
| | | | | | | | | | | | | B | 550 | 36 | 10000 | 43⅞ | 1870 | 27 | | 1905 |
| | | | | | | | | | | | | C | 550 | 36 | 10000 | | | | | |
| 2 | No 10 Vertical | Direct | 10" Inclosed Contracted | 925 | 925 | 6.68 | 24.03 | 30.71 | 7.75 | 11.46 | -.13 | A | 647 | 26½ | 7050 | | | | | |
| | | | | | | | | | | | | B | 646 | 25.5 | 6675 | 67⅞ | 1870 | 34 | | 5912 |
| | | | | | | | | | | | | C | 646 | 25.5 | 6925 | | | | | |
| 3 | No 12 Horizontal | Belted | 24" Inclosed Standard | 925 | 546 | 22.33 | 8.09 | 31.42 | 22 | 5⅞ | -.50 +2.17 | A | 600 | 27 | 8900 | | | | 8⅝" | |
| | | | | | | | | | | | | B | 594 | 24 | 9875 | | | | | |
| | | | | | | | | | | | | C | 594 | 20 | 7330 | | | | | |
| 4 | No 8 Vertical | Direct | 10" Inclosed Contracted | 925 | 925 | 5.43 | 24.57 | 30.00 | 6 | 11 | -.50 +1.00 | A | 641 | 28 | 6425 | | | | | |
| | | | | | | | | | | | | B | 642 | 25 | 6185 | 64 | 1870 | 31 | | 1909 |
| | | | | | | | | | | | | C | 641 | 27 | 6900 | | | | | |
| 5 | No 8 Vertical | Direct | 10" Inclosed Open | 920 | 920 | 5.43 | 24.57 | 30.00 | 6⅝ | 11⅛ | -.50 +1.00 | A | 540 | 37½ | 10173 | | | | | |
| | | | | | | | | | | | | B | 540 | 35 | 9675 | 41 | 1870 | 42 | | 1920 |
| | | | | | | | | | | | | C | 540 | 36.5 | 10173 | | | | | |
| 6 | No 8 Horizontal | Belted | 24" Inclosed Standard | 930 | 549 | 2.106 | 10.00 | 31.09 | 21⅜ | 3.9 | -.33 +2.12 | A | 538 | 14 | 4515 | | | | | |
| | | | | | | | | | | | | B | 538 | 23 | 6375 | | | | 4⅝" | |
| | | | | | | | | | | | | C | 538 | 14 | 4475 | | | | | |

* Full peripheral discharge

Results

| No | Pipe Friction Suction | Pipe Friction Discharge | Pipe Friction Total | Total Equivalent Lift | Discharge Gallons per minute | Discharge Cu. Ft. per Second | Pump Velocities Suction | Pump Velocities Discharge | Pump Velocities Periphery of Impeller | $V2gh$ | $6\sqrt{h}$ | Motor Input Watts H.P. | Motor Efficiency | Pump Input Mechan. H.P. | Pump Output H.P. due Static Lift | Pump Output H.P. due Total Lift | Pump Efficiency Static Lift | Pump Efficiency Total Lift |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.98 | 3.51 | 6.49 | Ft. 37.70 | 2621 | 5.84 | 5.38 | 10.72 | 71.82 | 1.61 | 12.93 | 41.02 | 90% | 36.92 | 20.71 | 25.02 | 56.1 | 67.8 |
| 2 | 2.07 | 2.20 | 4.27 | 34.98 | 1697 | 3.78 | 3.47 | 6.94 | 72.65 | 1.63 | 12.09 | 27.68 | 89 | 24.63 | 13.69 | 15.03 | 53.6 | 61.0 |
| 3 | 1.89 | 6.62 | 8.21 | 39.63 | 1931 | 4.09 | 5.09 | 5.19 | 57.17 | 1.27 | 10.30 | 33.15 | 92.5 | 32.51 | 14.57 | 18.37 | 44.8 | 56.5 |
| 4 | 1.36 | 1.12 | 2.49 | 32.48 | 1790 | 3.99 | 3.65 | 7.32 | 72.65 | 1.65 | 12.23 | 26.02 | 89 | 23.16 | 13.60 | 14.73 | 58.7 | 63.6 |
| 5 | 1.93 | 1.93 | 3.86 | 33.86 | 2810 | 6.26 | 5.74 | 11.48 | 72.26 | 1.64 | 13.17 | 40.24 | 90 | 30.22 | 21.30 | 24.09 | 58.8 | 66.5 |
| 6 | 3.27 | 0.75 | 4.02 | 35.10 | 1369 | 3.05 | 5.59 | 8.97 | 57.50 | 1.29 | 10.86 | 21.95 | 89 | 19.52 | 10.77 | 12.18 | 55.7 | 62.9 |

* Partial discharge

FIGURE 6.—HICKS ON CENTRIFUGAL PUMPS.

of efflux and the area of the opening, and that the height at which water is held will drop down in the pipe by an amount $h_2$ equivalent to the head necessary to overcome the frictional resistances created by the velocity of flow into and through the pump and aurifice. If the entire height h is used in the ordinary formula for discharge,

$$D = A \times c\sqrt{2gh}$$

instead of the correct height $h - h_2$, then the reduction of head due to the creation of velocity, the resistance to entry of the foot-valve and of passage through the pipes and pump openings, will take the form of a lower coefficient, and the variations of this coefficient for different values of h and D will furnish some indication as to the variation of frictional resistances in the pump. In other words, c represents the ratio which the actual discharge for any head h bears to the theoretical discharge, and includes all sources of loss. If the resistances were constant at all heads, then for constant value of A, D would vary as the $\sqrt{h}$. But, if for any reason, the net sum of the resistances change, the coefficient will also change. The numerical value of the coefficient is of no importance, because it would be relatively large or small, depending on the size of opening used.

The experiments, of which Figures 6 and 7 give the data and results, were made with a No. 4, standard pattern, horizontal shaft centrifugal pump, direct-connected to a 30-horsepower motor and in daily use for water-works service. The discharge through a six-inch pipe was connected into a measuring tank with a swinging elbow to waste-way. The pressure head was obtained by use of a valve on the discharge, the results being checked at several points by the use of a standpipe. It was possible to measure the suction depth directly, and the total resistances were shown by vacuum and pressure gages. The hydraulic data was taken with great care, equal in all respects to the tests heretofore described, but it was only possible to secure electric measurements on one leg, and the pump efficiencies are consequently valueless as exact statements, as there was no certainty that the load on the three legs was balanced. Nevertheless they are of considerable importance in showing the relative efficiency which may be expected at different lifts in terms of the maximum efficiency for given speed. The total hydrostatic head was secured by closing the valve on discharge pipe and taking the sum of the heights represented by the vacuum and discharge pressure as the value of H. The valve was then opened far enough to lower the pressure five pounds and the discharge was measured. Then another five-pound drop in pressure, and so on throughout the possible range of observation. The height $h_1$, representing the sum of static and frictional resistances at any point of discharge, has been calculated from gage readings for each point of observation. Also the value of the coefficient c has been calculated for the same points from the measured discharge, and with a value of $h_1 = H - h$. If the hydrostatic head H is drawn as a straight line, and the discharges in gallons per minute are platted as ordinates from the heights corresponding to the points of observation, and the extremities of these ordinates are connected, then will any ordinate to the curved line so formed represent the discharge at that height. Consider the nature and magnitude of the friction resistances in a centrifugal pump with an enclosed runner.

When maintaining a hydrostatic head without discharge, there are four principal sources of loss; namely:

First. The slip or back circulation around the suction inlet caused by the leakage of water from the discharge under a head due the static lift. As ordinarily manufactured, with leakage on both sides of the runner, and an opening of 1/32-inch around the suction inlet and balance ring, or when the bearings have worn slightly, this one item may account for 20 per cent. of the lost work. It evidently decreases with the height of lift.

Second. The frictional resistance of the circulated water across the side plates and through the vanes of the runner, approximately as the square of the velocity of flow, and as the flow is proportionate to the $\sqrt{h}$, this item also decreases with the lift.

Third. The drag of the runner periphery revolving at a high speed in water practically without velocity. The speed of the runner experimented with was 83 feet per second. When discharge is taking place the water in the throat and volute of the pump will attain a velocity proportionate to the area. Assuming, for instance, a velocity of flow of 15 feet per second in the same direction as the runner, this loss would be decreased approximately in proportion as $68^2$ is to $83^2$, the difference representing about 40 per cent. of the original resistance. As this loss decreases with the increase in velocity of flow, it evidently decreases with the lift.

Fourth. The friction of the side plates of the runner with the water in the pump shell. Since this is independent of pressure it will be a constant quantity for any height of lift.

Observed data – Test of No. 4 Centrifugal Pump for Electric Water Co. Sept 5th 1899

| No | Gages | | Static Heads Feet | | Discharge Valve | | Measuring Tank | | Electrical Measurements | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pressure | Vacuum | Discharge | Suction | Opening | Area | Time Seconds | Discharge Gallons | Transformer R.P.M. | Amperes | Volt Meter Volts | Volt Amperes | Watts | Power Factor |
| 1 | *19½ lbs | 4 lbs | 7.29 | 5.50 | Closed | 0" | | | 935 | 20 | 575 | 19993 | 17000 | 85% |
| 2 | 44⅜ " | 10 " | 7.29 | 9.33 | 20/50" | 1.70 | 374 | 12655 | 930 | 24 | 575 585 580 | 23251 | 20220 | 87 |
| 3 | 40 " | 14 | 7.29 | 12.66 | 33/50" | 3.09 | 264 | 15324 | 930 | 26⅓ | 580 590 582 | 25530 | 22474 | 88 |
| 4 | 35 " | 18⅞ " | 7.29 | 17.00 | 41/50" | 4.02 | 202 | 16528 | 930 | 29⅓ | 585 | 28161 | 25053 | 89 |
| 5 | 30 " | 24 " | 7.29 | 19.33 | 46/50" | 4.71 | 156 | 16054 | 930 | 31 | 582 | 29604 | 26548 | 90 |
| 6 | 25 " | 28 " | 7.29 | 21.25 | 52/50" | 5.28 | 154 | 17174 | 920 | 32 | 575 587 | 31610 | 29765 | 94 |
| 7 | 20 " | 28 " | 7.29 | 21.42 | 59/50" | 6.03 | 135 | 15342 | 920 | 31¼ | 585 578 | 30762 | 27685 | 90 |
| 8 | 15 " | 28 " | 7.29 | 21.42 | 67/50" | 7.11 | 145 | 16470 | 920 | 30½ | 588 587 | 29937 | 26493 | 90 |
| 9 | 10 " | 28" | 7.29 | 21.58 | 90/50" | 9.62 | 142 | 18109 | 920 | 29 | 585 | 27844 | 24781 | 89 |
| 10 | 7 " | 29" | 7.29 | 21.75 | 293/50" | 26.97 | 157 | 16612 | 920 | 27⅔ | 585 | 26573 | 23659 | 89 |
| 11 | 24½ " | 27 " | 49.29 | 20.83 | 293/50" | 26.97 | 140 | 15820 | 930 | 32½ | 584 | 31149 | 28190 | 90% |
| 12 | 16 " | 27" | 30.29 | 20.83 | 293/50" | 26.97 | 130 | 16880 | 920 | 31 | 585 | 29765 | 26785 | 90 |

* Add 1.29 ft distance from center of Pressure gage to point where Vacuum gage is connected
* At 7 lbs discharge pressure valve was wide open.
† Observation №11 and 12 were made by increasing the static head with a vertical Steel pipe 42 ft. of additional length on №11 and 23 ft. on №12. These observations are intended to check №6 and 8 above, as to the Comparative effect of discharge valve and Steel pipe

Bakersfield, Calif. Lewis A. Hicks Civil Engineer

Note: Pump direct connected to horizontal shaft motor

FIGURE 7.—HICKS ON CENTRIFUGAL PUMPS.

When discharge commences conditions are somewhat changed, since new elements of resistance are introduced. These are made up of the head necessary to create velocity of flow past the resistances offered by the pipes and pump passages, together with the kinetic energy lost in the form of discharge velocity. The sum of these resistances probably varies in a ratio somewhat less than the square of the velocity of flow, and therefore increases with a decrease in lift.

After discharge commences, it may be said in general that one source of lost work remains constant, three tend to decrease as the lift decreases, and one increases as the lift decreases. A careful consideration of the relative value of each of the factors of resistance, with due appreciation of the relative unimportance of fluid friction at low velocities, would, it is thought, lead to the conclusion that as the lift decreases the decrease in friction would be in excess of the increase due to velocity. This would continue until the increasing velocity friction throttles the discharge so that it ceases to follow an ascending ratio of the available head. This point may be called the breaking down point of the pump, or the point at which the discharge commences to represent a smaller percentage of the theoretical flow due to the area and the head, supposing the algebraic sum of the resistances a constant. In Figure 8 the theoretical discharge for different coefficients in gallons per minute has been platted as ordinates of the height of lift, and the variation in net resistance is clearly shown by the manner in which the line of actual discharge crosses the lines of constant resistance in an ascending ratio, attains a maximum, and then abruptly breaks down about the point where the velocity of flow through the discharge outlet of the pump becomes 15 feet per second.

You will notice that the experimental determination of flow amounts to rating the pump as a meter, so that the quantity being pumped into the main at any time may be ascertained from the reading of the pressure gage, and from the continuous record of an automatic gage, the daily flow may be computed with considerable accuracy.

If the discharge of a centrifugal pump at constant speed maintained a constant ratio to the head, the useful work performed would vary as the product of the weight of water discharged at any point into the height of lift. Expressed by formula,

$$\text{Useful work} = A \times c\sqrt{2gh} \times 62.5 \times h_1.$$

If the work for different heights is calculated by this formula and a constant value of c, and a curve is constructed by platting these values as ordinates to a line

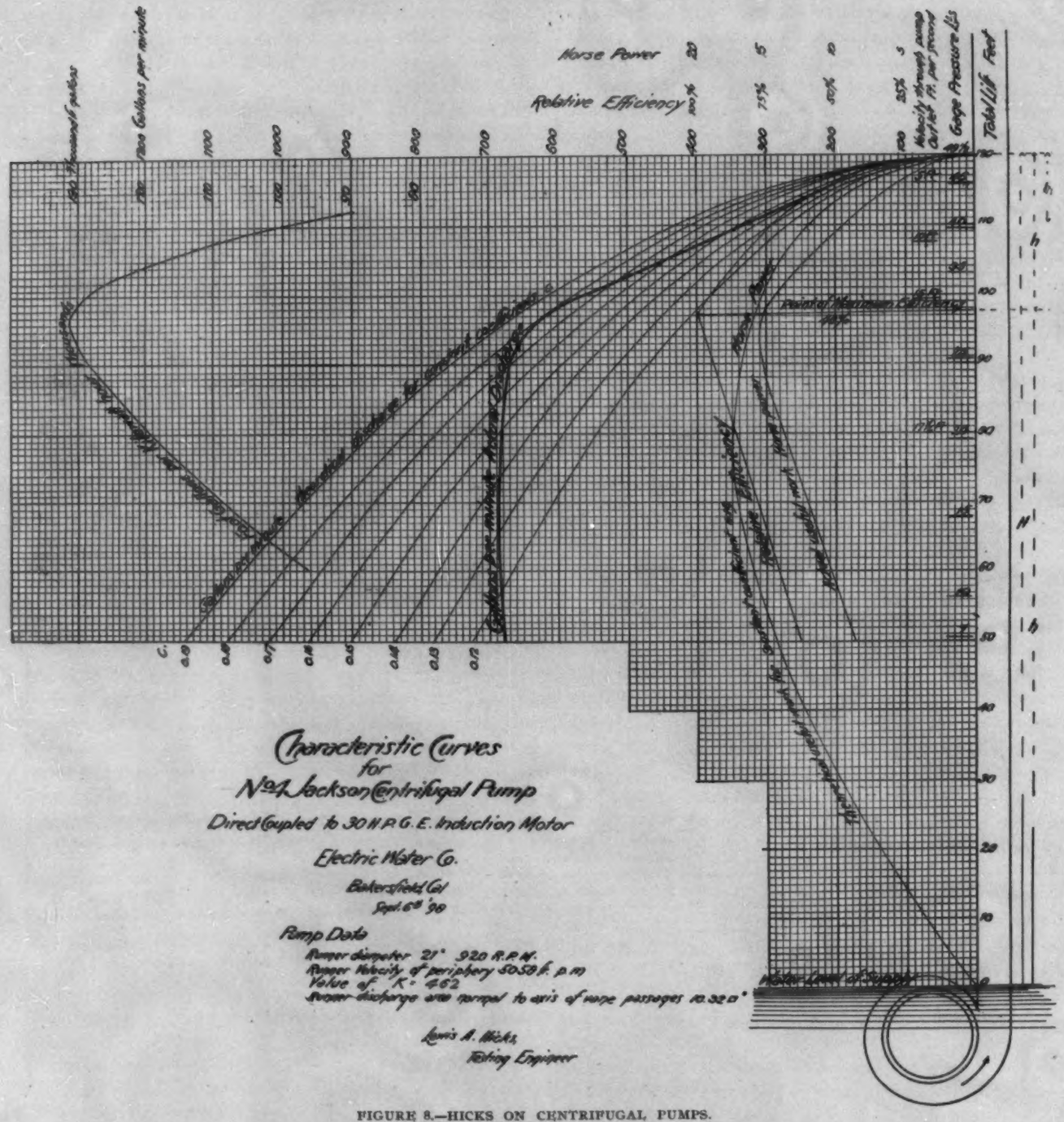



FIGURE 8.—HICKS ON CENTRIFUGAL PUMPS.

representing the hydrostatic head, it will be found that this will always assume the form shown in Figure 8.

h increases as $h_1$ decreases, and the mathematical relation is such that the curve will always attain its maximum at $\frac{2}{3}H$, the total hydrostatic head, and if the resistances were proportionately uniform the maximum efficiency of the pump would be attained at the same point. In practice the maximum efficiency occurs at the breaking-down point of the discharge, when the ratio of discharge commences to decrease.

The actual work is shown in Figure 8, together with a curve of relative efficiency which is platted merely to show how closely it follows the curve of useful work in form and peculiarities. It seems evident, in view of this agreement, that if through favorable changes in the water ways of the pump, the discharge line could be maintained past the present breaking-down point, the efficiency would be very considerably improved. The actual efficiency may have been slightly more or less than shown, depending on how nearly the load was balanced in the three legs.

It is thought that the methods herein described offer a rational mode of investigating the so-called mysteries of the centrifugal pump, and that a wide range of observa-

tion along similar lines in the hands of competent designers may be expected to produce better pumps, which is the consideration that interests all of us. It is therefore with the idea of provoking discussion which may lead to a better understanding of the subject that the writer presents the tentative methods of analysis herein described.

Centrifugal pumps are commonly relegated to low lifts on the ground of inefficiency at high lifts. There appears to be no practical reason for this conclusion, and on the other hand the writer possesses experimental data which warrants the belief that efficiencies of 70 to 75 per cent. may be reasonably specified and required for lifts of 100 feet and over.

The length of time that this efficiency can be maintained in a given pump will depend on the amount of sand pumped, the excellence of the design and workmanship in the matter of minimizing back circulation and providing water-ways for low velocities, stiffer spindles, first-class bearings with self-oiling rings, a better grade of packing, and finally, upon the case with which the bearings are maintained and lubricated. The high speed of revolution makes it somewhat difficult to maintain packing successfully against vacuum pressure; but when purchasers demand a higher standard of excellence, and these matters receive the same intelligent care given to other machinery, there will be something of a revolution of opinion regarding centrifugal pumps. It is manifest from the tests submitted that the pump in use is not suitable for its work, and yet, with the low efficiencies shown, the results compare favorably with large high-duty plants elsewhere. The cost of pumping 1000 gallons to a height of 100 feet for fuel and attendance ranges from ½ cent to 1¼ cents for steam, and from ⅛ cent to ⅜ cent for water power. It will be seen from Figure 8 that at the ordinary working pressure in the mains, 130,000 foot-gallons were pumped per kilowatt-hour. Assuming capital invested in transmission plant at $250 per horsepower, and a load factor of 50 per cent., the probable cost of horsepower to the consumer would be not far from $50 per annum, or about ¾ cent per kilowatt-hour, making the cost per 100,000 foot-gallons about ⅝ cent. This could be improved with a pump adapted to its conditions to an average duty of 200,000 foot-gallons per kilowatt-hour, or at the rate of ⅜ cent per 100,000 foot-gallons.

Where cheap current is available and suction conditions permit the setting, a centrifugal pumping plant suitable to supply a city of 5000 people with motor, transformers and all equipment, including housing, can be installed for $2500. This would provide two pumps set on a common base on either side of motor, to which they would be direct-connected, with suitable by-pass connections so arranged that ordinarily the delivery would be directly into the main, the peripheral runner speed being adapted to create 40 to 50 pounds working pressure. In case of fire the opening and closing of a couple of valves would instantly run the pressure up to 100 pounds.

A duplicate plant could be installed for less than the ordinary investment in tank storage, and by leaving a pulley between the motor and pump, and a beltway to a gas or steam engine, the risk of interrupted service would be minimized. The consideration of relative first cost, and fixed charges so created, gives a yet more favorable showing. It is well known that the most economical pumping engine is not the one showing highest efficiency in terms of coal consumption, but that in which the sum of the fixed charges and coal cost is least.

The application of this philosophy to the centrifugal pump leads to the conclusion that a properly designed plant of this type in units up to 5,000,000 gallons capacity, is economically superior to any other installation; and that where circumstances are favorable to the use of electricity, the simplicity, compactness, and automatic regulation of these plants is unexcelled. Where steam is used, centrifugal pumps attaining an efficiency of 70 per cent., and connected to triple-expansion condensing engines, capable of producing an indicated horsepower-hour with 15 pounds of steam, may be expected to give a duty of 65,000,000 to 75,000,000 foot-pounds per 1000 pounds of steam, and, owing to the enormous difference in first cost, compare favorably in economic performance with high-duty machinery attaining a duty of 120,000,000 to 150,000,000 foot-pounds and a mechanical efficiency of 95 per cent. These considerations must, in time, make the centrifugal pump an important factor in water-works service.

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# *Electric Lighting versus Gas.**

*BY JOHN MARTIN.*

WHEN I became interested in electric lighting some four years ago, due to an investment in a water transmission plant furnishing light and power, the subject of proper rates for illumination became a matter of investigation for me, which I have continued up to the present time. This investigation brought me in contact with gentlemen operating both gas and electric plants, whose opinions were so greatly at variance that it became almost compulsory to experiment in order to obtain anything definite as a proper basis for the service rendered. The conclusions which I have reached are based upon personal experience, which may be of some interest to others, at least to the extent of bringing out a discussion from practical sources which may lead to a better understanding of this great problem that is ever present to managers of lighting plants.

Unbounded enthusiasm and blind prejudice were so strongly embedded in the minds of many managers of both electric and gas plants, that very little was accomplished in the matter of a fair and straight adjudication of rates and service until they came in contact

*A paper read before the Third Annual Convention of the Pacific Coast Electric Transmission Association, San Francisco, June 20-21, 1899.

with the opposing method of illumination, usually brought about by consolidation. This enabled the opponents to get a proper appreciation of the merits and shortcomings of the previously opposing method of artificial illumination.

When electric lighting was first introduced, it was the custom for the promoters to load the plant with excessive first cost, and, comparatively, very inefficient apparatus. The results then obtained caused the gas men to become confident that electric competition would not be serious. So true was this that when the Welsbach burner was first presented to them they spurned it as an evil to be avoided, for by its use the consumer's bill would be decreased.

After some years of evolution the electric installation has been greatly perfected, its cost materially reduced and its efficiency very largely increased. The gas men in self-defense took up the active use of the Welsbach burner, which to-day is their greatest help in competing with incandescent electric lighting.

The usual methods previously in use in competition were such that when a company would establish very low rates for one kind of artificial illumination, the manager of the opposing company would either decide that the opponent would surely go into insolvency at a moment's notice, or resort to the usual method of making a reduction for his illuminant. This was usually persisted in by both companies until each lost money in the sale of current or gas for illuminating purposes. Both sides became content with a false idea that they were pursuing the proper course because they saw nothing but failure ahead for their competitor, whereas, at the same time they failed to appreciate their own unfortunate losing situation. The many losses sustained in this vicious method of competition usually resulted in a consolidation of interests, and after a thorough knowledge of both methods of illumination, these companies have since become profitable without excessive rates being charged to the consumer.

When competition presents itself at this day, the wise manager makes it a business to study closely the full strength of his adversary, and if a vicious competition is unavoidable, he considers it his duty to arrange his rates to give at least a small profit to his company, if by doing so he can compel his adversary to suffer loss. If, on the other hand, he finds that competitive rates would cause his company a loss, and at the same time were high enough to enable the opposition to make a profit, he then considers it his duty to make the first advance looking towards a consolidation, or a working arrangement with his adversary whereby both can live.

In determining the question of rates, the following fact is usually lost sight of in assuming the ability of your adversary to maintain low rates, namely: *Low rates are always conducive to largely increased consumption.* Larger output insures reduced cost of production, so that when a gas plant cannot pay with its present consumption at less than $3.00 per thousand, yet with a quadrupled consumption it can pay at $2.00 per thousand; or an electric plant hardly paying expenses at 20 cents per thousand watts, may under similar conditions of increased output pay handsomely at 12 cents per thousand watts.

Several months ago I addressed communications and questions to many managers East and West, asking for information as to rates, character of installation, competition and success of competing companies, from which I will quote (without specific reference), and at this juncture desire to express my thanks to all for their kindness and consideration in giving the information asked for and their ideas of policy.

As this paper is being submitted mainly for the consideration of the proponents of electric lighting, I desire to present several opinions as expressed in answers to the following query:

In your judgment what plan is best to adopt to successfully cope with gas competition, and at what prices for gas is your plan based?

Among the answers I received the following:

From a large New York plant:

Gas, 95 cents per thousand. Incandescent lights, 20 cents to 10 cents per kilowatt-hour.

In my judgment, to compete with the Welsbach, we should avoid too active a campaign as it would tend to excite the gas interests to great activity. The Welsbach's popularity is soon lost owing to decreasing candlepower, disagreeable light, and short life of mantles.

From a New Jersey plant:

Gas, $1.50 per thousand. Electric light, 13½ cents per kilowatt-hour.

Low rates and good service, with enough business enterprise to call the attention of the public to the decided advantages of electricity as an illuminant, will easily meet gas competition. If all houses in our territory were wired, we would have little difficulty in securing most of them as customers, because wiring old houses stands in the way of our getting many customers who are otherwise anxious for the light.

From a Massachusetts plant:

Gas, $1.25 per thousand. Incandescent light, 23 cents to 12½ cents per kilowatt-hour.

We compete quite successfully with gas at prices named, by giving good service and the conveniences of electric light over that of gas. Also the fact of electricity being more healthy.

And a few selections from Pacific Coast plants:

The best plan is to consolidate; if not, fight fire with fire by the installation of a modern gas plant as an adjunct.

With small consumers, namely, residences, suggest flat rate based on a specified number of lights burned at one time with an overload meter or overload vibrator for excess.

Good service and low rates. Rates to be about equal to gas rates, candlepower for candlepower. There are large separate fields for both gas and electricity.

From these answers it is fair to assume that the average electric lighting company is on a progressive and profitable basis, but it should not be inferred that

gas plants are not. The reduction in prices of gas for fuel has opened a very large and profitable field for the gas companies heretofore unoccupied by them, which has compensated partially, if not wholly for the loss of sales for illumination. Such being the case, the increased production of gas for heating purposes has prompted the gas companies to lower their rates for illumination, generally without specific losses. It is therefore unwise for managers of electric plants to believe that gas plants are on the decline, and in a condition bordering on decay. While it may be, and is probably true, that enormous profits are a thing of the past, yet with good active management a gas plant may continue in business without serious loss, in competition with an electric plant, if properly managed and every legitimate economy adopted. From this I do not desire the gas man to establish false hopes in the theory that if they can at least make a small profit now, they may eventually hope to make a larger profit in the future.

The improvements in the electric service are so marked and rapid that there is little hope left for the gas plant as a very profitable competitive illuminant, unless working arrangements are made with the opposing company.

I will now consider from a theoretical standpoint the two methods of artificial illumination.

The candlepower of illuminating gas that is furnished throughout the United States ranges from 16 to 20 candlepower, and I have assumed 18 candlepower as the value of the average gas so furnished, burning 5 feet per hour in an open burner.

The consumption of a 16 candlepower incandescent lamp ranges from 50 watts to 70 watts per lamp, and I have assumed 60 watts as an average consumption for a 16 candlepower lamp. The average consumption of gas through a 4-foot tip is approximately 6 feet per burner per hour. The consumption of gas through a Welsbach burner averages 3 feet per hour per burner. The average candlepower of a Welsbach burner is 42 candles.

With the use of an open-tip burner 1,000 feet of gas consumed will produce 3,600 candle-hours. In the use of a Welsbach, 1,000 feet of gas will burn 333 1-3 hours, producing 14,000 candle-hours.

In order to produce a theoretical equivalent of illumination, the 16 candlepower incandescent lamp will have to burn 225 hours to equal the consumption of 1,000 cubic feet of gas through a common-tip burner, which aggregates 13½ kilowatt-hours, and in theoretical competition with the Welsbach burner, it would have to burn 875 hours, consuming 52½ kilowatt-hours of electric current.

On this theoretical basis, with gas at $1.50 per thousand, using a common-tip burner, electric current should be sold at 11 1-9 cents per kilowatt-hour. If gas is $2.00 per thousand, at 14 8-10 cents per kilowatt-hour. Gas at $2.50 per thousand, 18 2-10 cents per kilowatt-hour, and gas at $3.00 per thousand, 22 2-9 cents per kilowatt-hour.

The theoretical rate in competition with the Welsbach with gas at $1.50 per thousand, current should be sold at a little less than 3 cents per kilowatt-hour, and a proportionate increase for the higher prices of gas.

From the above it is obvious that the open burner cannot successfully compete on the Pacific Coast with the incandescent lamp, and it may be assumed that the Welsbach burner holds a mortgage on efficient illumination.

While the above figures are based entirely on theoretical equivalents, there are practical conditions which effect the proportions to such an extent as to introduce a personal equation. These conditions can be summed up as follows:

Among the objections to Welsbach lighting, as determined by the consumer, are, first, decreasing candlepower; second, disagreeableness of the light changing from incandescent white to a yellowish green; third, brittleness of the mantles; fourth, difficulty in lighting; fifth, limited sphere for decorative effect; sixth, vitiation of the atmosphere. These objections permit the sale of current for incandescent lighting at higher prices because of a large number of consumers who are willing to pay a little more for illumination, when the above objections are eliminated, as is the case with the use of the incandescent lamp.

The personal equation above named also makes the use of Welsbachs permissible, for there are a number of consumers who are willing to submit to the objectionable features enumerated and thereby effect a financial economy in illumination.

The conditions existing on the Pacific Coast, where a large amount of electric illumination is produced by use of water power, and current is sold at flat rates, the question of cost of illumination in competition with Welsbachs is very largely removed. The rates charged in California for residence purposes will average 25 cents per 16 candlepower lamp per month, 24 hours service, and 80 cents per light per month for business purposes.

The eastern managers as a rule, and some of our western managers, believe firmly in the sale of current by meter measurement exclusively, while California managers have established flat rates almost entirely. It is a fact that the only satisfactory basis for selling current produced with fuel is on meter basis, and many managers also argue that all illumination should be so charged.

From the standpoint of a manager of a water-power installation, I must take issue with the latter contention. When current is produced by a water-power plant (and by this I mean a plant having ample water power for its installation through the entire twelve months of the year), the establishment of the flat rates has proven satisfactory in many plants in California. It has the one advantage of eliminating disputed ac-

counts. Each patron knows in advance what his light bill will be, which is alike satisfactory to business men and housewives. The restriction in extravagant use of current with flat rates is the life of the lamp, the renewals for which the customer pays.

By making very low rates per lamp installed, the home is wired more liberally, and my expereince demonstrates that the low rates for residence use has increased the consumption per lamp very materially. This means better illumination for more hours per day, than when sold by meter measurement. The old habit of turning off the light to effect economy, has vanished, and with it comes the fortunate disease of good, liberal illumination. This disease becomes infectious, until finally the entire town is afflicted. This affliction is indeed a blessing; the homes are more cheerful and pleasant, and at the same time the feeling of extravagance is not experienced.

Admitting that the only restraint in consumption is the cost of renewals, the question arises as to what compensation does the electric company obtain for its service. From personal experience I find that with an average of 500 consumers at residence rates, the amount of current furnished equals 38 per cent. of the total capacity of the lamps installed. Assuming an average residence rate of 25 cents per 16 candlepower lamp, we obtain an average revenue approximating 66 cents per lamp current per month, or about $7.00 per horsepower per month. This leaves the current available for day service power, which can be disposed of on a profitable basis. It is true that some plants are selling power in large units at from $5.00 to $10.00 per horsepower per month for 24-hour service. From this it is evident that illumination at these low rates is profitable even after paying the additional interest on the investment, and the depreciation, cost of maintenance, operation and repairs of the distribution system. In business houses the rates are necessarily higher, because all lights are used at the time of peak load. This peak load is the determining factor of the capacity of the plant. The development of the day service for power at some plants produces an average 24-hour load factor ranging from 70 per cent. to 80 per cent. of the peak load.

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# *Hints on Long-Distance Transmission.**

*BY R. W. VAN NORDEN.*

IN stringing the wire for the new circuit between the Auburn power house, recently erected, and Sacramento, the supply of large triple-petticoat glass insulators gave out and temporarily standard two-petticoat glass insulators with teats, were used to support a mile of wire. These latter were closely watched, especially in wind and rain. While the former often cracked or split, and in some cases set poles on fire, the ordinary insulators showed no signs of weakness. Locust pins were used, and as an extra precaution every pin was boiled in paraffine until thoroughly soaked. So far as can be ascertained by careful observation there has been no cracking, splitting or leakage, and no arm or pin has been burned or charred. The line has been cut out and thrown in suddenly every day for nine months; but while the water in a storm hangs from the teats and drips near the wire or upon the arms, no results detrimental to the proper working of the line have been observed. Several large glass insulators have passed through severe storms without accident, though badly cracked. It is therefore a natural conclusion that boiling the pins in paraffine is of extreme importance.

The possibility of synchronizing the machine at Auburn with the Newcastle generators, the distance between the stations being some five and one-half miles, and the line of No. 4 copper wire, was seriously questioned by some authorities, who claimed that as the capacity of the line was small, the effect would be to cause a current lag or a change in the form of the electromotive force curve and make the machines pump or altogether fall out of synchronism. Not the slighest difficulty of this nature was experienced. In fact when Station No. 2 comes in, the operator at Station No. 1 hardly knows the moment, there being only a slight movement of the ammeters.

At present all regulation (the system is hand regulated) is done at Station No. 1. Station No. 2 starts up with a specified load, and as the general load increases, at a telephone signal Station No. 2 augments its own load 100 horsepower at a time, every hour or half hour, until the maximum is reached. The operation is then reversed until Station No. 2 is cut out entirely.

By this method no water is wasted at Station No. 1, where it is valuable for irrigation, etc., while at Station No. 2 the water must flow constantly, this station being on the same canal but farther up the country.

If for any reason the generator in Station No. 2 be underexcited, the difficulty can be remedied by overexciting the lower generators. This causes a slight flattening of the electromotive force curve, however, so that a wattless current flows between the stations, which tends to make the voltmeters fluctuate very slowly but regularly about one volt; and the ammeters become unsteady.

The distance seems to have a cushioning effect and it is not by any means so necessary to have the generators so near in synchronism when thrown together, as when side by side.

It is therefore evident that stations may be distributed over considerable distance and yet run as one, all aiding to swell the total of current to be delivered.

*A paper read before the Third Annual Convention of the Pacific Coast Electric Transmission Association, San Francisco, June 20-21, 1899.

# On the Determination of a Fair Return for Current Supply.*

BY C. WM. HUTTON.

THE question of a proper method of arriving at a schedule of charges for current supply is vexed and unsettled, but certainly one that will repay close investigation. The prevailing practice seems to be a sort of intelligent guesswork on the part of the majority of electric companies.

In dealing with a subject of this kind it will be found impossible to lay down any fixed method that will cover all cases, but at the same time, by the method herein proposed, it will be found that the same general principles of arriving at the cost of current supply will hold good in any case, and thus enable an electric company to establish rates, which, when applied, will make each customer, as near as possible, a profitable adjunct to the station. This general plan has already been proposed in connection with steam plants supplying current, and is not, therefore, original with the writer. I find, however, that it is particularly applicable in the case of waterpower transmission plants, and will therefore present it for your consideration.

To establish this rate, which varies with each plant with local conditions, it is necessary only to know the average of the peak load for the several months of the year that the station in question is called upon to carry during the year, the drop and current losses between the switchboard and the customer during this load, the interest charges including dividends, the proper charges for depreciation on the whole system, the general expense charges, which may be assumed to be fixed, and the average generating and delivering cost per kilowatt-hour. The sum of the interest and dividend, depreciation and general expense charges for the year represents the total fixed charge. The average peak load, less the current and copper losses, will represent the customer's average demand at peak load, and the former divided by the latter expressed in kilowatts gives the fixed charge per annum for each kilowatt actually used at peak load.

Assume for the purpose of illustration a waterpower transmission plant of say twenty miles, which has an average peak load throughout the year of 3,530 kilowatts at the sub-station distributing switchboard. The capacity of the generating machinery for such a load should not be less than 4,500 kilowatts allowing for all contingencies.

| | |
|---|---|
| Assume the cost of the electrical equipment of such a plant to be | $300,000.00 |
| The waterpower development, including water-wheels and accessories | 250,000.00 |
| The distributing system from sub-station (overhead lines) | 100,000.00 |
| Lands, buildings, etc | 100,000.00 |
| Franchises and other property | 50,000.00 |
| Making a total investment of | $800,000.00 |
| Allowing 6 per cent. for interest and dividends on this amount, we have | $48,000.00 |
| Depreciation at 4 per cent. on the whole system | 32,000.00 |
| The general expense account, including salaries of officers, accounting and office expense, legal expense, collection, canvassing, taxes, insurance, etc., would probably not be less than | 46,000.00 |
| So that the total fixed charge per annum would be | $126,000.00 |

The average maximum switchboard load having been 3,530 kilowatts, and the loss in *distribution* at this average load being taken at 15 per cent., the customer's average maximum demand would be about 3,000 kilowatts, so that each kilowatt supplied at this maximum would be chargeable with $126,000.00 divided by 3,000, or $42.00 per annum to cover the so-called fixed expenses, and each customer who uses all his connected load should pay this sum per kilowatt capacity wired, as well as the actual cost of current delivered for each kilowatt-hour supplied to him. This price will be prohibitive to the customer who uses service only for a very short period at the time of maximum load, but public policy requires the company to supply all applicants who can pay for the service, and at a price, in this case, not to exceed, say 10 cents per kilowatt-hour, so that the loss sustained through this class must be made up from the customers who use current more continuously. This may appear unjust, but in reality it is less so than the ordinary system of charges, by which a customer having twenty lamps, and using them all ten hours per day, pays the same rate as the customer having two hundred lamps connected and uses them only one hour per day. The latter is the most unprofitable customer, and should pay the maximum rate, while the other is entitled to a liberal discount.

The method here suggested of determining the rate which can profitably be made to such customers is based upon the length of time they use the current. If, for example, in the plant described, the average cost of generating and delivering a kilowatt-hour (based on the assumption that we have a delivered load factor of fifty per cent., and that the actual operating expenses outside of those above enumerated is $2,700.00 per month) is one-fourth of a cent, and a customer who burns all his lamps should have twenty lamps, or one kilowatt capacity connected, and consumes 250 kilowatt-hours in a month, his bill would be one-twelfth of $42.00, or $3.50 for fixed charges, plus 62½ cents for generating cost, or a total of $4.12½, making a rate of 1¾ cents per kilowatt-hour consumed. If the same

*A paper read before the Third Annual Convention of the Pacific Coast Electric Transmission Association, San Francisco, June 20-21, 1899.

customer's meter showed a consumption of 125 kilowatt-hours for the month, he would have averaged one-half of the hours burning as in the previous instance, but he would be charged $3.50 as before for fixed charges, plus 31¼ cents for generating cost, or a total of $3.81¼, which would make his rate slightly over three cents per kilowatt-hour consumed. In both cases he has paid the interest and depreciation on that portion of the investment necessary to supply him his share of the general expenses and the cost of generating the current he has used. The rate per kilowatt hour of monthly consumption for each kilowatt capacity called for at peak load can be readily determined from a curve constructed from the data of each individual plant.

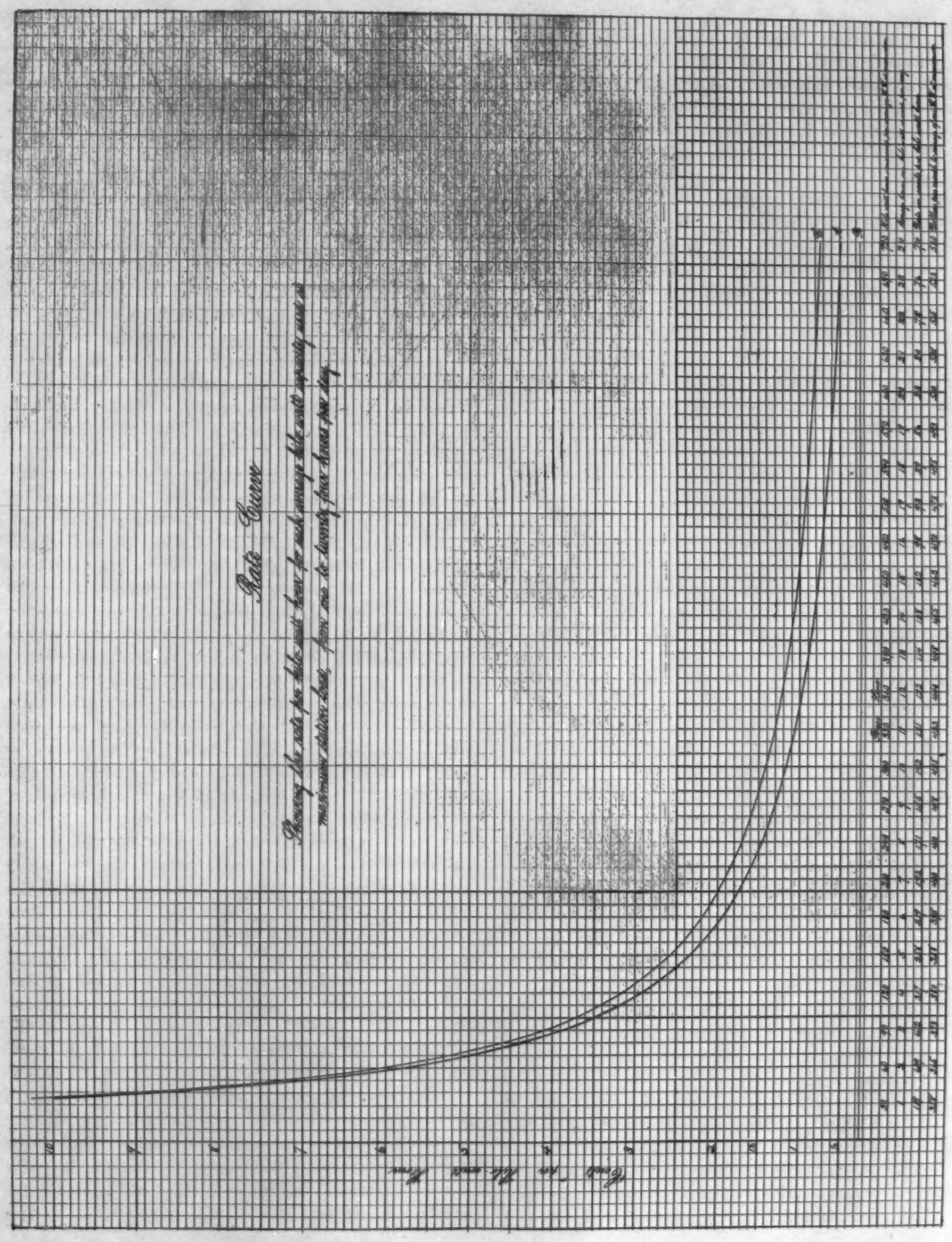
The accompanying curve gives the charges under the conditions existing in the station used for illustration. The kilowatt-hours on monthly meter readings per kilowatt capacity called for at peak load is laid off horizontally, and the cost in cents per kilowatt-hour vertically. A curve, *A*, is first plotted, the ordinate for any point of which is determined by dividing $3.50 (one twelfth of the annual fixed charge) by the abscissa in kilowatt hours. A horizontal line, *B*, is then drawn through the point in the vertical scale, expressing the average generating and distributing cost in cents per kilowatt-hours, in this case one-fourth of a cent, and the sum of these two, curve *C*, gives the rate per kilowatt-hour for any monthly meter reading. In order to ascertain the proper rate for a customer who calls for more or less than one kilowatt capacity at peak load, the monthly meter reading should of course first be divided by the kilowatt capacity he uses.

It will be seen that by this system for determining the minimum rate at which day customers (and long-hour night customers as well) can be profitably supplied applies equally to those having very few lamps or very small motors as to those having large installations, and by extending its principles to such small capacity consumers with relatively high monthly consumption, a very large amount of business, which is to-day compelled to use other illuminants or other sources of power, might be taken on the electric companies' circuits with profitable results. These rates, as shown by the curve, are necessarily power rates, being based on the assumption that the obligation of the company ceases with the delivery of the current on the premises of the customer. If, therefore, as is customary with a great many electric companies, lamp renewals are furnished, or in the case of arc lighting, the average extra cost of the same per kilowatt-hour should be added to the power rates.

One point in particular in connection with the rate curve is very noticeable, and that is that a customer using small capacity, but showing a relatively high monthly consumption, either for light or power, would be charged at an exceedingly low rate per kilowatt-hour. In fact, a rate that would be so very much lower than the rates of any other possible method of furnishing illumination or power that a considerable advance could be made in the rates to such customers and still destroy all competition by other methods. The revenue from such source can therefore be made to compensate in a measure for such loss as would be sustained through furnishing current to the short-hour customer with a heavy demand.

The very important question then arises as to what form of current-measuring apparatus shall be used to carry out the principles of this system of charges. The ideal meter would, of course, be one that would show the customer's average maximum demands in kilowatts, together with total number of kilowatt-hours consumed during the month. An attachment has, I understand, been recently put on the market which, when used in connection with a watt-hour meter, will register the customer's load for each day on a moving strip in such a manner so that the *average* maximum for the month can be readily obtained, which, together with the watt-hour reading, will be all that is required. Another recent device has also been brought out, whereby the *maximum* demand is indicated by the use of the ordinary forms of watt-hour meters, to which the above device is attached. The maximum demand being indicated by making use of the torque exerted by the armature on the drag disc. The upper or motor part of the meter, carrying an indicator, is flexibly coupled to the lower or drag portion, which consists of a disc on which is plotted the kilowatt scale. A pawl and ratchet prevents the relaxation of the spring, so that the device indicates the maximum kilowatts that has passed through the meter during the month. This latter device would, therefore, answer the same purpose as the well known combination of a Wright demand indicator, whien installed in connection with a regular watt-hour meter, but with the advantage that the two instruments are combined in one. Still another method that has recently been advocated is the use of two-rate wattmeter, by which method a customer is charged at a higher rate for consumption during the peak load hours than for other hours. These three latter devices are good in a way, as they tend to keep down the peak load, and in a double way increase the load factor, for it not only *keeps down the peak load*, but *encourages the long-hour customers*, and especially will this be so in the case of distribution from a water-power electric transmission as against electrical distribution from a steampower plant, because of the relatively high fixed charges as compared with generation and distribution charges in the case of the former.

This fact is so very noticeable that it would appear that a flat rate based on the average demand of the ordinary class of customers could be made that would answer all purposes, and it can if some method be devised whereby it is possible to know the customer's average maximum demand. I say *average*, because it would not be right to charge a customer who may want


Rate Curve
Showing the rate per kilowatt hour for each average kilowatt per month
maximum demand hour, from one to twenty-four hours, inclusive.

HUTTON ON EQUITABLE RATES.

to use, say, double the amount of current for a few hours at some particular time during the month on the basis that such double load is his daily demand, excepting, of course, the case of a store which closes early five nights in the week and remains open during the entire peak load hours on the sixth night. Such cases will require special rates; in any case, that will depend to a considerable extent on other conditions. The great objection to placing any of the measuring devices that are known to the writer on the premises of each and every customer is the excessive cost of all present forms. As has been shown, any device which will enable the charges to be based on the average maximum demand has the tendency of *keeping down the peak load*, which is of the utmost importance, and increasing the load factor. It will be seen, however, that increasing the load factor of the average customer would be of very little advantage to the electric company, as it would increase the revenue from these customers but slightly; for increasing the total load factor of the entire system from fifty per cent. to one hundred per cent. would halve only the one component of the total cost, viz.: the generating and distributing cost—in this case one-fourth cent per kilowatt-hour, which, in any event, would be a very small portion of the average customer's bill; and even in the case of a power customer using his power, say twenty-four hours per day and twenty-six days in the month, it would decrease the total cost of his power less than sixteen per cent.

From what has been shown, the following conclusions may be drawn as to what method shall be used for determining a fair return for current supplied by waterpower electric plant where the conditions approximate those given in the plant used for illustration, having roughly the following class of customers to supply:

Class 1. Those which use current for power purposes from eight to twenty-four hours daily in units of more than five kilowatts capacity.

Class 2. Those which use current for motors of less than five kilowatt capacity and for lighting stores, saloons, residences, etc., using the current for from two to twelve hours daily, and are always on during the peak load hours.

Class 3. Those which use current for lighting large early-closing stores, which close at six o'clock on five of the week day nights and remain open until ten o'clock the sixth night.

Class 4. Those which use current under a special contract which stipulates certain hours that the current may be used for the purpose of keeping their load off during the peak load hours.

For customers coming under the head of class one, an instrument should be provided that will not only indicate the number of watt-hours consumed during the month, but should also give an indication from which it would be possible to arrive at the customer's average maximum demand for the same period. With these figures at hand, and by reference to the price curves, the proper rate per kilowatt-hour will be determined.

For the majority of customers who would come under the head of class two, a simple and comparatively cheap device is required. In one form an instrument could be made which could be set to carry a predetermined amount of current which would be sufficient to supply the customer under ordinary conditions, but that would open the circuit if a greater amount were drawn for any length of time, and would close the circuit again, remaining closed providing the maximum current for which the instrument is adjusted is not exceeded. In addition to this, the instrument should be provided with an attachment which would enable the customer at his own discretion to change the adjustment so as to allow him to use a greater predetermined amount of current for such time as he may desire, the attachment being so arranged that in changing the adjustment he would wind and set in motion a simple clockwork that would register the number of hours during the month he had used the current while the instrument was adjusted for this increased demand. An instrument of this kind in a mechanical form, such as a circuit breaker, could be cheaply made up about as follows: The brake would be made by a solonoid, drawing out the switchblades against the tension of a spring, the solonoid being actuated by means of the expansion of a metal strip designed to carry the supply current, making such a contact that the solonoid would be thrown in circuit and thus open the switch. The load being off, the metal strip would immediately cool and the contraction of the same would open the solonoid circuit, thus allowing the spring to close the switch, when current would be supplied as before. The opening of the circuit would, of course, be an indication to the customer that he was using more current than for which he had contracted.

On the side of the instrument would be arranged a rack rod, which, when pushed in once, would shunt the metal strip with a given resistance, and at the same time wind and put in motion a simple clock device connected to a train of gears on which would be arranged hands that would indicate on a dial in hours. One push on the handle would run the clock device for one hour, when it would release the shunt, restoring the instrument to its original adjustment, the clockwork stopping at the same time. If it was desired to use extra current for two or more hours, he would push the rack two or more times, as desired, thus winding the clock sufficiently to run the desired number of hours. The company would thus be enabled to know that the customer's ordinary demand did not exceed a certain amount, and also the number of hours he had exceeded this amount. Another form of instrument, that would be somewhat simpler, and perhaps less likely to get out of order, would be the well known

Wright demand meter, with the addition of a clock mechanism and shunt attached to the meter on the same general lines as in the instrument already described.

For those customers who would come under the head of class three, a demand indicator would be required that would give such a reading that it would be possible to obtain the customer's maximum demand for each day in the month. Customers of this class are the very worst with which the electric companies have to contend; but as the revenue from such sources is an inviting plum, it will always be found desirable to take them on the circuits, though this business in itself would represent a loss were it not possible to make up such loss from the customers who use the current more continuously.

The customers under the head of class four are the most flexible and desirable of any, as they can be used to fill in the hollows of the load line in any way desired. They are a class that belong almost exclusively to the electric companies, who, as a general rule, transmit their energy several miles over pole lines, running through fertile farming country. Especially is this true in this State, in which the vast valleys are used in nearly every instance for agricultural purposes. The principal uses to which power will be put would, therefore, be for the purpose of running irrigating pumps. As these customers would be kept off during the peak load hours, what revenue would be obtained from them would be practically a clear profit. Very low rates could, therefore, be made which would be an encouragement for extended usage. Their charges would therefore be on a basis of a certain price per kilowatt-hour, regardless of their demands. The ordinary form of watt-hour meter would, in these cases, answer all purposes.

In offering these suggestions of a method of establishing a rate, it is not claimed that it will exactly fit each individual case, but the application of its general principles will fit any case, especially the plan of constructing a rate curve from the data of each individual plant, as herein outlined, as it would enable any electric company to ascertain whether and to what extent some of its doubtful customers represent a profit or a loss, and to guard against making unprofitable contracts in the future.

## LONG SPANS OF OVERHEAD WIRES.

According to Professor Juellig, the maximum spans possible for wires of different materials on a basis of a factor of safety of 4 is as follows:

| | |
|---|---|
| Cast steel wire | 3.42 miles |
| Silicon-bronze | 1.56 to 1 mile, depending on quality |
| Wrought iron | 1.02 miles |
| Soft copper | 0.53 miles |

These maximum spans are independent of the cross-section of the wire, for although the weight of the wire increases with the cross-section, its strength increases in the same proportion. The spans given do not allow for wind pressure, snow or ice.

# Illumination

## ELECTRIC RAILWAY TRAIN LIGHTING.

THE most remarkable feature in the revival of electricity for train lighting is that it has been mainly caused by one system, the invention of A. B. Gill. So widely has it appealed to railway men that already it is in use on upwards of one hundred railways, including several American railways. The details of a method which has practically created a revolution in the illumination of trains is obviously of interest. In its essential feature it consists of a dynamo placed underneath the carriage, being driven from the axle. To merely drive a dynamo from the axle of the carriage is one of the oldest arrangements in train lighting. It was done on the Midland, on the Brighton and South Coast and in Australia many years ago. But it is not difficult to conjure up the difficulties that such a method must contend against. All systems that embrace driving from the axle must provide some means of meeting the variation in speed of the train. It is in the manner of solving that problem which gives to the various systems their distinctive characteristics.

The simplest method that would occur to an electrician, says H. Scholey in *Cassier's Magazine*, would be to utilize the excess current generated by increased speed, to partially demagnetize the field magnets, thus keeping the output of the dynamo within certain definite limits. This formed the basis of more than one method, but they each necessitated delicate means of governing, and this was partially responsible for their comparative failure.

In the Stone system there is a complete departure from this method of compensating for speed variation. The dynamo is suspended from the under frame of the carriage in such a position that its driving pulley is practically on a level with the axle pulley, from which it is driven by a belt. By such means it is claimed that none of the vibration or vertical motion of the axle is transmitted to the dynamo. The substantial difference between this and former systems is that, no matter how great may be the variation of speed, the dynamo always runs at a fixed speed, and consequently produces practically a constant amount of electricity, and this is achieved in a comparatively simple manner.

The dynamo is suspended from the carriage by one corner, and is held by means of an adjustable link in such a manner that it is free to swing. When connected by means of the belt to the axle pulley, the link may be so adjusted that the driving belt draws the dynamo out of its natural position. This adjustment is regulated to give a definite tension on the belt sufficient to absorb power equivalent to the amount of electricity required. In other words, it is possible by means of the adjusting screw attached to the suspending link to set the machine to supply a certain definite number of lights. In endeavoring to seek its natural position the dynamo exerts a pull on the belt. As long as the axle pulley runs within the certain limits, its pull on the belt is no greater than that of the dynamo; when, however, the train increases its speed the axle exercises a greater pull on the belt, and this has the effect of drawing the dynamo towards the driving pulley, with the result that the belt slips while the armature continues to revolve at its normal speed. Increased speed means more slip, and in that we have the secret of this system of train lighting.

"Several of the engineering papers from the JOURNAL have been read and discussed before the assembly of the National Association of Stationary Engineers here with profit," writes the secretary of the San Diego, Cal., association in renewing his subscription.

It is an unexplained, but indubitable fact, asserts the *Gastechniker* that acetylene kept in its holder for some days falls off in lighting power, and that this deterioration is well marked even after twelve hours.

An electric automobile has attained a speed of 63.6 miles per hour in France, the record being made for the second kilometer in a run of two kilometers.

THE JOURNAL OF
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## EDITORIAL.

**THE POLICY OF THE JOURNAL.**

The change which is apparent in the title of this publication in the present issue, is due to several causes, the most particular one resting in the fact that the interests it has fostered so long are of a composite rather than of a specific nature. *The Journal of Electricity* has not excluded from its columns all save that which pertains to electrical matters. It has devoted great space to considerations of the applications of hydraulics, of steam power and of the gas engine; these not only as prime movers but each in its own peculiar fitness in the attainment of the golden goal of highest possible efficiency. Compressed air, too, has received due consideration, for its importance in the constellation of transmission agencies is far from being inconsequential. Above all, modern engineering does not purport a blind devotion to electricity or gas or steam or pneumatics; but instead, the adaptation of either or several or all these as may best satisfy the conditions existing to most eminent fitness.

Say what one will, a publication devoted to a specific channel of engineering must inevitably, though perhaps innocently and unconsciously, become biased in its advocacy of the interests it represents. Are there gas papers that discuss the electric light with absolute fairness, or electrical publications that do not retaliate? Are there journals devoted to compressed air that do not depreciate the electric motor, or, *per contra*, electrical magazines which rise above their secular animosities and endorse compressed air as a motive power in instances wherein it is inherently the best fitted for such? Similarly, and to illustrate the point more forcibly, are there water wheel manufacturers frank enough to admit that conditions requiring a moderate distance electric transmission from a waterfall may exist wherein the installation of steam would be profitable, and the utilization of the energy of the waterfall would be a commercial failure? Of these, there may be some, but they are numbered among the hopeless minority.

Better is it then, by far, that a publication which aspires to and actually attains an absolute impartiality in its treatment of the respective merits of the natural agencies for the conversion, transmission and distribution of energy, should be forever freed from whatever might restrict the utterance of unprejudiced opinions. Capital is seeking profitable investment the world over, and the new problems constantly arising, together with the almost kaleidoscopic changes being made in some branches of engineering development, lend further emphasis to the necessity stated.

It has thus been determined to broaden the title of the JOURNAL that its true aim and scope may be more clearly defined.

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**IT MEANS BUSINESS.**

At last the monopoly which has held the electric lighting business of San Francisco in its grip ever since the inception of the industry, is to be broken, for the man who has the hardihood and cash with which to offstand the assaults of the sugar trust and to bring it to its terms; who has the courage and power to drive the entering wedge that, in the Valley Road, is soon to release the relentless grasp of the Southern Pacific Company upon the throat of the mercantile interests of California; the man who almost, if not quite above all others, has time and again proven his unfaltering loyalty and devotion to the advancement of the interests of the Golden State, has said that the electric lighting monopoly in San Francisco is to be broken as soon as men, money, and human ingenuity can do so. More than that, he has put his own resistless shoulder in earnest to the wheel, and this is what has resulted:

On March 28th of the present year, the Independent Electric Light and Power Company was incorporated; but prior to that date its plans were well matured. Within three months thereafter contracts had been awarded for machinery and construction work amounting in the aggregate to more than two million dollars, and the preliminary work of the installation is now progressing with the greatest possible speed consistent with thoroughness and the best engineering practices. It is expected that the new system will be in operation early during the coming winter.

When the projected plant is in operation, San Francisco will possess an installation that will be a noteworthy electric transmission as well as a central station which will be the peer, if not the superior, of any in the world. In brief, steam power generated on the water front will be electrically transmitted to sub-stations by three-phase, high-potential, underground conductors, and from these

sub-stations the various characters of service will be run underground, first to the business sections of the city and afterward to the residence portions.

To be explicit: The generating station will occupy the block bounded by Twenty-third, Humboldt, Louisiana and Georgia streets, adjoining the California Sugar Refinery, in Potrero, San Francisco. The contract awarded to the Babcock & Wilcox Company provides for the early installation of eight batteries of the well-known Babcock & Wilcox double-deck boilers of wrought steel construction, and having a capacity, according to the Centennial rating, of 6000 horsepower. Each of the eight batteries will consist of three such boilers, or 24 boilers in all, and the boiler plant will be operated so that there will always be two batteries in reserve. Induced draft will be used and an equal capacity in Green economizers and Stratton separators and receivers will be erected under the original contract. The engine equipment will consist of three $\frac{28 \times 58}{48}$ vertical cross-compound McIntosh & Seymour engines, running at 116 revolutions per minute and delivering 2400 horsepower each with 165 pounds of steam. Each engine is guaranteed to deliver 4200 horsepower under $^{6}/_{10}$ cut-off. In addition, two $\frac{9\frac{1}{2} \times 19}{15}$ vertical tandem McIntosh & Seymour engines, each running at 210 revolutions per minute and delivering 150 horsepower, are to be installed.

The electrical machinery is to be that of the Westinghouse Electric and Manufacturing Company throughout. Direct-connected to each of the three larger engines is to be a 1500-kilowatt revolving armature, 500-volt two-phase generator, while the two smaller engines will each drive similarly a 150-kilowatt, 125-volt engine-type exciter. The plant will operate at 60 cycles. Seven 750-kilowatt transformers will take the the two-phase generator potential and deliver it to the underground mains at 11,000 volts in three-phase current. Three, or possibly four, sub-stations will be installed in the business sections of the city, involving a transmission of between four and five miles. The sub-stations will contain lowering transformers delivering 2200-volt three-phase current for the operation of rotaries, and for direct delivery to the underground distribution at that electromotive force. Direct-current 110-volt, three-wire distribution will also be made under the Lamme system* as in use notably in the Hartford and San Gabriel transmissions. In addition to driving the larger sizes of polyphase motors direct, the 2200-volt three-phase underground mains will operate transformers in the manholes for supplying the low-tension alternating distribution circuits. The installation of direct-current series arc lighting circuits is not contemplated at present—although it may be done—as it is believed that the alternating-current enclosed arc lamp has at last reached the stage of commercial perfection. Obviously, the 2200-volt mains may supply transformers for the delivery of any desired potential or phase from any of the manholes, which, with the direct-current circuits from the sub-station, will enable the delivery of any class of service desired. The "block" system will be generally adhered to in the low-tension distribution, and the manhole transformers will ordinarily run in 100, 50, and 25 kilowatt sizes. Lead-covered multiple cable will be used exclusively in the original work, and the contract awarded for this aggregates approximately 2,000,000 feet. The contract for the entire underground conduits and subways provides for the placing of sewer tile conduits, laid in cement. The only overhead work at present contemplated is a line extending from the Potrero power house to the power house of the San Francisco and San Mateo Electric Railway Company, at Sunnyside, a distance of nearly five miles. Power delivered by this proposed line will drive rotary converters for the operation of the street railway system, thus displacing its present more or less antiquated steam plant.

These are the general features of the system under which the Independent Electric Light and Power Company is to operate, and that they will be adhered to is evidenced in the fact that their installation is contracted for. Engineers will be quick to recognize that the designers of the new plant have, in general, thoroughly grasped the trend of modern central station design; but some will take exception to the use of step-up transformers, with their consequent losses, when the delivery of 10,000 or 12,000 volts at the terminals of the generators is already a well-demonstrated success, and to the use of distributing transformers in small sizes with low all-day efficiencies when the sub-stations, as arranged, provide a competent means for supplying the low-tension mains from station transformers or rotary converters and under such an arrangement as will assure the highest possible attainment in general and all-day efficiencies.

The present inflated condition of the copper market is a misfortune to the electrical industry and may do much toward disproving, in this instance, the accepted belief that money invested in copper is better than that invested in transformers; still there will be found many who will be unyielding in the contention that, under existing conditions, the increased costs of interest and attendance for low-tension distribution from large units in sub-stations direct, will be materially less than the costs attending operation under the plan adopted where the insidious losses of low all-day efficiencies find a convincing proof of their existence in the abnormal size of the consequential coal bills.

But these considerations are foreign to the point at issue: San Francisco is about to be released from its enthrallment at the hands of the soon-to-be-broken electric lighting and power monopoly; and certain it is that an era of unprecedented cheapness awaits the long-suffering electricity-consuming public of the metropolis of the West.

*See *The Journal of Electricity*, Vol. VI, No. 5, pages 98-9, November, 1898.

### *ON THE INEFFICIENCY OF ACETYLENE.*

Many instances could be cited wherein the interests of legitimate corporations would be well subserved were they to enter into a vigorous campaign for educating the public in technical matters to such an extent as would enable it

to eventually discern fact from fiction. To do so is the province of all trade journals in their respective lines, and the manner in which the *Progressive Age*, a well known gas paper, has taken up the subject of the economy of acetylene gas as an illuminant in competition with city gas, is exemplary. From the beginning that publication has been pronounced in its support of acetylene as having its own niche in the problem of economy in the gas world, and in the pursuit of its investigations it is actuated by the desire to produce facts and only facts.

The extravagant statements in the catalogues of American acetylene generator manufacturers as to the efficiency of acetylene has led to a widespread illusion that in its use may be derived a method of illumination by gas that will enable each family, for instance, to produce the new gas for all purposes at considerably less expense than the cost of service from city mains. These catalogues are reproductions of each other very largely, and all contain comparative statements of the superiority and cheapness of acetylene over all other forms of lighting. Nine of them represented the cost of producing 100 candlepower-hours to vary from $2.27 to $7.50 for city gas, against from $1.09 to $2.40 for acetylene. The ratio of cost in the compilation varied from 1.0 to 4.2, with an average of 2.6; or in other words, these nine catalogues made the contention that, in general, city gas is 2.6 times as expensive as acetylene for equal illumination. The gross error of these statements brands them as unpardonable misrepresentations.

The catalogues referred to assumed the use of 10, 15, 16, and 18 candlepower coal gas. Although 16-candlepower coal gas is common in England and France where very little little water gas is used, in the United States coal gas runs from 18 to 22 candlepower, and water gas from 22 to 30 candlepower per five cubic feet per hour. The assumption of 22-candle gas will be under rather than above the average. The candlepower of acetylene per five cubic feet consumption per hour is represented to be "250, 300, and even 400 candles," but conservative authorities place it at 240 candles. Further representations place the price for city gas to average $3.00 per thousand, while a thousand cubic feet of acetylene is declared to cost variously from $5.45 to $12.00. The fact is that the average price for city gas is nearer $1.50, while at the present prices acetylene will cost the consumer at least $13.33, although in the two cases of town lighting now in operation by acetylene in the United States, the price is $20.00 per thousand at the consumer's meter. The price of carbide in 100-pound drums, f. o. b. at Niagara, is 4½ cents per pound, to which the consumer must add the cost of transportation and the dealer's expense and profit. Tests at the acetylene exhibition held in London last summer showed that the best automatic generators delivered 4.5 cubic feet of acetylene gas per pound of carbide, from which is to be deducted say, six per cent. for leakage—which is low—leaving a production of 4.2 cubic feet per pound. This figure is for the best of the automatic type, but poorer classes of generators were found to yield as low as 3.5 cubic feet per pound. Consumers of carbide for this class of work will pay from five to 8 cents per pound for carbide, with an average price of 5.6 cents per pound, and these figures show the cost of producing acetylene to be $13.33 per thousand as stated.

On this basis, which represents actual conditions closely, the cost of illumination per 100-candlepower-hours is as follows:

| | |
|---|---|
| City gas | $1.36 |
| Acetylene | 2.77 |
| Ratio | 0.05 |

Under average conditions, therefore, city gas costs about one-half as much as acetylene for equal illumination, and not 2.6 times as much as acetylene generator makers claim.

### THE EDISON THREE-WIRE PATENT.

A subscriber asks for the date of expiration of the Edison three-wire patent, and also if it would be legally considered an infringement of said patent if three wires were used of equal area or gage; that is, if the neutral wire is the same in size as either outside wire.

The United States letters patent for the Edison three-wire system of electrical distribution is dated March 20, 1883, its number being 274,290. As it is a 17-year patent, it expires on March 20, 1900.

Any combination of circuits in which the neutral or "compensating conductor" is carried back to a division or neutral point in the sourse of energy, whether it be dynamos in series or a dynamo with a third brush, or primary or secondary batteries, or a transformer or transformers or otherwise, or whether it be a three or four or five wire system or more, is clearly covered by the patent specifications. Obviously, therefore, the use of three wires of equal cross section as described would constitute an infringement, so long as the neutral is by any manner carried back to the compensating point of the source of supply.

### THE STORY OF THE THREE EGGS, IMPROVED.

One of the installation engineers of General Electric Company, who is particularly well known in the Pacific Northwest, and who, being of Norweigan descent, frequently becomes mixed in his "j's" and "y's," was asked in Portland recently if he had heard the story of the three eggs. Though the story referred to is an ancient chestnut, still he said he had not heard it.

"Two bad," exclaimed the other, with a twinkle.

The G. E. man looked serious a moment, and then came the dawning which found expression in his relaxing features and the sage observation:

"That's a good yoke!"

### SIEMENS & HALSKE ALTERNATING MACHINERY.

If competition is the life of trade, activity in lines of transmission installation and general alternating current work will be materially increased in the near future by the accession of the Siemens & Halske Electric Company of America to the list of the large electrical manufacturing concerns producing that class of dynamo-electric machinery. Announcement is made by the Siemens & Halske company that within six months it will be prepared to

deliver all classes of electrical machinery, and, in addition to the superior direct-current apparatus it is now manufacturing, especial attention will be given to the production of high-grade transformers, meters, and single, two and three phase generators of all capacities. It will, therefore, be a representative electrical manufacturing concern in all branches of the trade, and as such, it will be welcomed by all save its competitors.

### PROFFESSOR FORBES MAKES A CORRECTION.

Prof. George Forbes has submitted the following self-explanatory communication relative to the paper read by himself before the Society of Arts, London, on the long distance transmission of electrical power:

In a paper of mine (reprinted in abstract in the number of the *Journal of Electricity* for June, Vol. VII, page 97) some tables are given for facilitating calculations connected with the transmission of electrical energy to a distance. In Table III (page 99), the column of current densities, with an inefficiency of 1.3, is wrong, and as these columns may probably be copied, I desire to give the correct values of the current densities at the inefficiency 1.3 for the different distances and electric pressures indicated by the reference letters A to K. These are as follows:

| | | |
|---|---|---|
| A 1064 | D 266 | G 152 |
| B 532 | E 215 | H 133 |
| C 355 | F 177 | K 89 |

## Personal

J. A. LIGHTHIPE, engineer of the Pacific Coast office of the General Electric Company, has been in the East for a month past that he might attend the annual gathering of the district engineers of the General Electric Company at Schenectady.

R. S. MASSON has resigned the electrical engineership of the San Francisco office of the Westinghouse Electric and Manufacturing Company, and has accepted the position of assistant general manager of the Independent Light and Power Co., San Francisco.

W. R. SUMMERHAYS, general manager of the Mutual Light and Power Company, San Francisco, is in the East presumably for the purpose of letting contracts for the installation of modern apparatus in the new station which the Mutual company is building.

E. W. SUTCLIFFE has retired from the position of electrical engineer of the Central California Electric Company, Sacramento, that he might accept a similar position with the Butte County Electric Power Company, the new power transmission being installed for Chico, Cal., and vicinity.

### LOCALIZING FAULTS IN CONCENTRIC CABLES.

THE practice of burning out faults in underground conductors has the disadvantage of often obliterating all traces of the cause of the fault, and indeed it seems unnecessary to do so in view of the fact that faults may be accurately located and removed without burning out or reducing their resistance to less than about 1000 ohms. Two English methods of doing this are described by Hamilton Kilgour in a paper read before the Northern Society of Electrical Engineers.* Assume that a fault in a concentric cable is to be localized, in which event the testing set or bridge is connected as shown in Figure 1, wherein $r$ is a known resistance, variable at will, and $f$ is the fault to be localized.

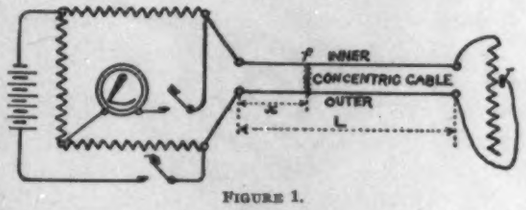



FIGURE 1.

If A = resistance of the fault plus the resistance of the inner and outer conductors up to the fault;
B = parallel resistance of the fault and circuit formed by the inner and outer conductors beyond the fault and the variable resistance, plus the resistance of the inner and outer up to the fault;
C = resistance of inner and outer of the whole length of the cable in series, which is assumed to be known in advance;
$r$ = value of the variable resistance;
$x$ = distance in yards to the fault as shown in the figure;
L = length of the cable in yards, as shown; then

$$x = \frac{B - \sqrt{[(A-B)\{(C+r)-B\}]}}{C} L$$

and, after preliminary trial, it is not difficult to assign a value to $r$, which will give accurate results if care has been taken in making connections, allowing for testing the leads, etc.

Murray's loop test is, however, considered preferable to the above, inasmuch as it is unnecessary to attempt to determine the resistance of the fault. In it, either the inner or the outer conductor of the concentric cable (preferably the inner as it is the more likely to be intact) up to the fault forms one arm of the bridge as shown in Figure 2; the remaining part of the conductor and the return lead (which may be the inner or outer of another cable, or a special cable laid along the road surface for the purpose of the test) from the far end of the faulty cable forms the second arm; one set of the proportional coils and the variable bridge resistance form the other two arms of the bridge; whichever of the

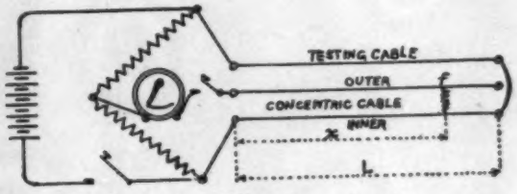



FIGURE 2.

two conductors of the faulty cable that is not used as above described, is employed as the galvanometer lead to the junction of the two arms of the bridge at the fault, all as shown in Figure 2.

If A = ratio of the resistance of the faulty cable conductor (used as one bridge arm) up to the fault to the resistance of the remainder of this conductor and of the return lead in series;
B = ratio of the resistance of the return lead to the resistance of the whole length of the conductor used as a part of the bridge;
L = length of the cable in yards;
$x$ = distance in yards to the fault; then

$$x = \frac{A\,(1+B)}{1+A} . L$$

Or, if $A' = A$
$B' = 1/B$

$$x = \frac{A'\,(1+B')}{B'\,(1+A')} . L$$

It is stated that after localizing a fault by this method, it has occurred more than once on dissecting the fault that there has been found merely a single parted wire in the outer conductor, the solder being still visible, and a tiny pin hole through the inner insulation immediately below one of the free ends of the broken wire, the cable being otherwise quite uninjured.

*The Electrician*, Vol. XLIII, No. 6, June 2, 1899.

# Gas

## INDUSTRIAL GAS.—IV.

BY FRANK H. BATES.

THE HEMPLE APPARATUS. When it is desirable to make an accurate analysis of a gas mixture in the laboratory, and when time is not an important factor, the Hemple apparatus affords a means, and is, in consequence, very largely used.

*Description.* The simple gas burette, Figure 7, consists of two glass tubes, A and A′, which are connected by a thin rubber tube about 120 centimeters (about 47.24 inches) long. The ends of the tubing are simply closed

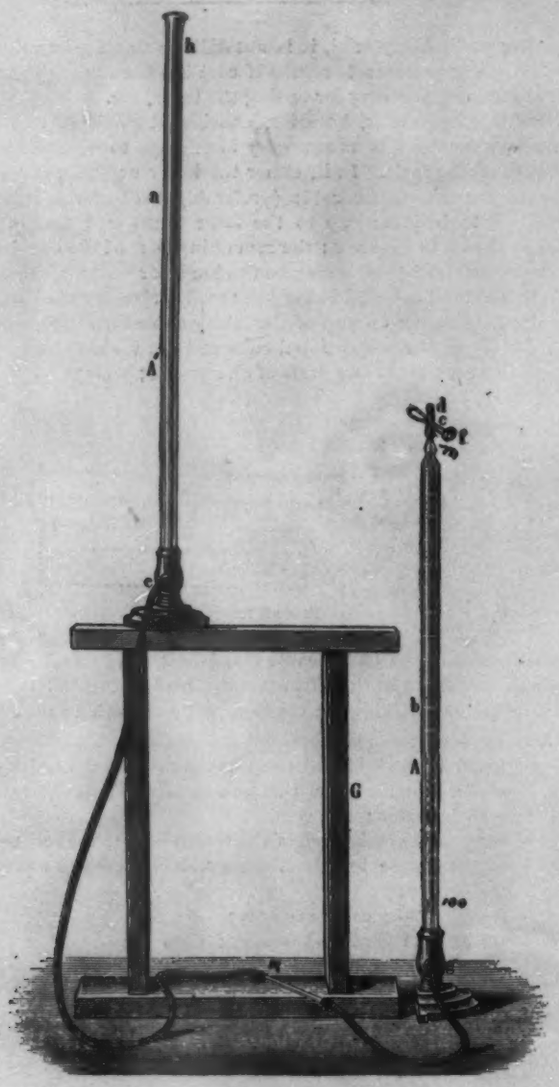
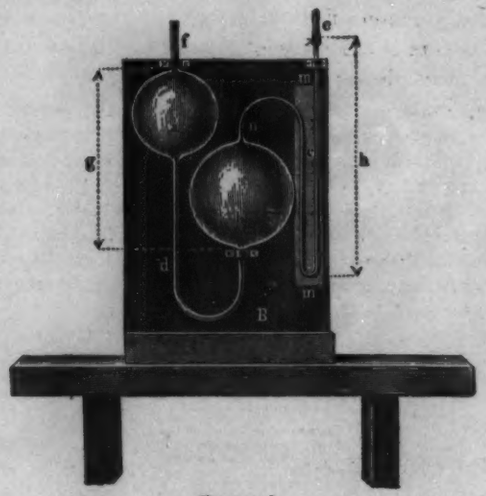



FIGURE 7.

over a projecting glass tip from each burette, and made fast by wrapping tightly with string. To facilitate the cleaning of the burette, the rubber tube is divided in the middle and the two ends, R R′, joined together by a piece of glass tubing. Inside the feet, the tubes A and A′ are bent at right angles and conically drawn out. They resemble, in general construction, the tubes described in the first number of these articles. The tube A is calibrated so as to contain exactly 100 cubic centimeters between the upper extremity and the lowest graduation, and is drawn out at the end to a thick walled tube *m*, while the tube A′ is widened at the end to a mouth *h* for the reception of liquids. The tube A, or measuring burette as it is termed, is supplied with or without glass stop-cocks. A piece of rubber tubing over the end *m* may be closed in a completely satisfactory manner by a Mohr pinch-cock, *f*, which




FIGRUE 8.

is put on close to the end of the capillary. Hemple states that he found it much easier to make tight rubber tops and connections than perfectly tight glass stop-cocks, wholly aside from the fact that by giving up the glass cock the apparatus is rendered less fragile and less costly. The writer prefers the glass cocks however, and has found that no trouble need be experienced in their use when they are kept well lubricated, as heretofore directed. If pinch-cocks are used they must be removed from the rubber tubing after using, and in the use of either pinch-cocks or glass stop-cocks occasional tests must be made to make certain that no leakage is possible. Notwithstanding the fact that readings cannot be made under the rubber tube, and that the pinch-cock cannot always be put on above the tube in exactly the same position, no error results therefrom, since the glass tube is very small. Hemple found that differences in volume are much less than one-tenth of a cubic centimeter, a variation which, in determinations not made over mercury, may be entirely disregarded.

The graduations on the measuring burette A are divided into fifths of cubic centimeters, and the numbers run both up and down.

*Operation.* To briefly review the method of operation: Fill the tubes A′ and A with water which has been saturated with the gas to be examined, taking care to drive all air from the connecting rubber tube, by suitably raising or lowering the tubes; then join the burette A to the vessel containing the gas by means of a glass or rubber tube filled with water. This tube is readily filled by

simply raising the level-tube A'. To fill the burette with the gas to be examined, grasp the tube A' in the left hand, close the rubber tube at *e* by pressing it between the little finger and palm of the left hand, and pour out the water in A'. Place the level-tube A' on the floor, and open the pinch-cock *f* on burette A. The water will now flow into the level-tube A' and draw the gas into the burette A. As soon as A is filled with gas, close the pinch-cock *f*, disconnect A from the gas holder, and after waiting three minutes for the liquid to drain down the walls of the burette, take up the level-tube A' by the iron feet, and by raising and lowering bring the water in both tubes to the same level. The gas is now under atmospheric pressure, and its volume is read off. To measure off exactly 100 cubic centimeters, bring somewhat more than 100 cubic centimeters of the gas into the burette, close the latter with the pinch-cock (or glass stop-cock), and let the water drain down for a period of three minutes. Now compress the gas to less than 100 cubic centimeters by raising the level-tube; close the rubber tube at *g* with the thumb and first finger of the left hand, set the level-tube on the table, and, raising the burette A with the right hand to the level of the eyes, carefully open the rubber tube (held closed by the left hand), and let the water run back until the meniscus stands at the 100-cubic centimeter mark, when close rubber tube again and open the pinch-cock *f* for a moment, when the excess of gas will escape and there remains in the burette exactly 100 cubic centimeters of the gas under atmospheric pressure. The above directions illustrate Hemple's method for obtaining a sample of exactly 100 cubic centimeters; the writer however, would suggest the method described in the first number of these articles in connection with the makeshift apparatus, by which a little more than 100 cubic centimeters of gas is drawn into the burette, then compressed to exactly 100 cubic centimeters, when the excess pressure is relieved by opening the stop-cock or pinch-cock for a moment, thereby giving just 100 cubic centimeters under atmospheric pressure.

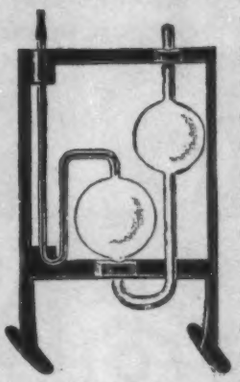


FIGURE 9.

The Hemple apparatus provides a special pipette for each reagent, so designed as to make the absorptions rapid and thorough and yet protect the reagents from dilution or weakening by the absorption of air. As each pipette (the vessel used to contain the reagent) is in turn connected to the gas burette, the following description of the various pipettes will serve to familiarize the reader with their general operation.

*The simple absorption pipette*, Figure 8, consists of two large bulbs, *b* and *a*, joined by the tube *d*, and of a thick-walled glass tube, *n c*, of one-half to one millimeter internal diameter, and bent as shown in the figure. This tube will be termed the capillary tube. The bulb *a* holds about 100 cubic centimeters and *b* about 150 cubic centimeters, so that when 100 cubic centimeters of gas is brought into *b*, sufficient space for the absorbing liquid will remain. To protect the pipette from being broken and to facilitate its manipulation, it is screwed to a wooden or iron standard. Figures 8 and 9 show the wooden and iron supports respectively. On account of the different behavior of wood or iron and glass toward changes of temperature and atmospheric moisture, it is advisable to

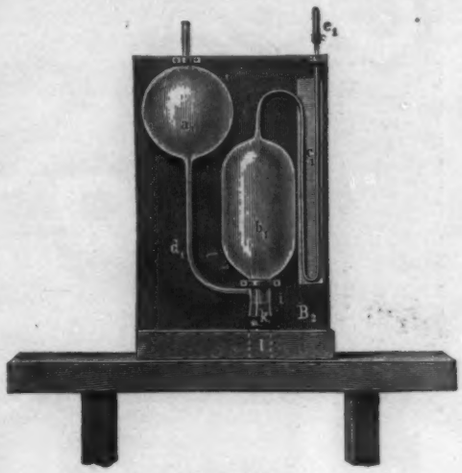


FIGURE 10.

fasten the glass at only three places by means of metal bands and sealing wax, the capillary tube being allowed to project from two to three centimeters above the frame. A short piece of rubber tubing is wired on to the free end of the capillary. The distance *h* (Figure 8) must be greater than *g*, so that it may be possible to enclose a gas between two columns of liquid in the pipette.

*The simple absorption pipette for solid and liquid reagents.* The only difference between this and the simple pipette is that in place of the bulb *b* (Figure 8), there is inserted the cylindrical part $b_1$ (Figure 10), which can be filled with solid substances through the neck *i*. A cork or rubber stopper *k*, held in place by a wire, closes the neck. A glass tube (Figure 11) closed at the top, and over which a rubber ring, cut from a rubber tube is drawn, makes an excellent stopper. By this arrangement only a narrow strip of rubber is exposed to the action of the reagent. See Figure 11.

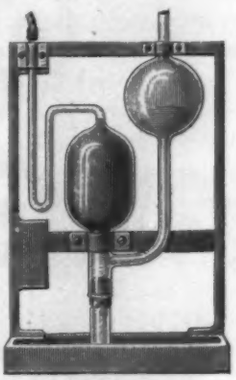


FIGURE 11.

*The double absorption pipette.* Reagents which are acted upon by oxygen—potassium pyrogallate, cuprous chloride, ferrous salts, etc.—cannot be kept in the aforementioned pipettes, since the reagent would, in a short time, become inactive through contact with air. The double pipette overcomes this difficulty, permitting the use of the reagents under an easily movable atmosphere which is free from oxygen, and the reagent employed may be kept completely saturated with those constituents of the

gas that it does not strongly absorb, this being a great advantage. The pipette consists of the large glass bulb *a* (Figure 12), of about 150 cubic centimeters capacity, and three smaller bulbs, *b*, *c* and *d*, each containing only 100 cubic centimeters. They are connected by the bent tubes *e*, *f* and *g*, and end in the bent capillary tube *k*.

*The double absorption pipette for solid and liquid reagents.* The construction may be easily understood from

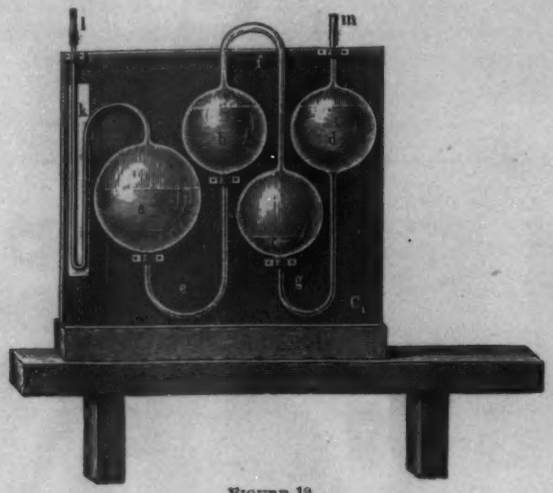


FIGURE 12.

Figure 13, and what has already been said in reference to the simple pipette for solid and liquid reagents.

To prepare the double pipettes for use, introduce the solid substance to be employed, if any, and then fill the pipette completely with the gas to be analyzed by slowly drawing the gas through. Now pour water through *m* into the bulb *d* until *g* is full. Close the rubber tube *l* with a pinch-cock, insert into it a thin glass tube at least one meter long, and fasten a funnel to the upper end of the latter by means of a piece of rubber tubing. Upon pouring the reagent into the funnel, the pressure due to the height of the column enables it to quickly pass through the capillary tube *k* into the bulb or cylinder *a*. The action may be hastened by gentle suction at *m*. After about 100 cubic centimeters of the reagent has been introduced, the bulb *d* is nearly filled with water and the gas remaining in *a* is driven out through the long tube by blowing into *m*. The pipette is now closed at *l* and shaken for some time to remove from the bulb *b* the gases absorbable by the reagent. After driving out any gas bubbles which may be in *a*, suction is applied at *m* and so much gas is sucked out of the bulb *b* that the liquid in *d* will enter and fill *c*. If the water first poured in is not sufficient, more must be added from time to time.

In pipettes thus prepared the tubes *k* and *e* and the bulb *a* are filled with the aborbent, the space from *b* to *f* with a gas free from oxygen, *c* and *g* with water, and *d* with air. While the reagent in the simple pipette may be considered to be saturated with gas only when it is kept in continual use, that in the double pipette on the contrary, remains saturated for an exceptionally long time, since the diffusion must take place through the confining 100 cubic centimeters of water and through the narrow tube. The error caused by this theoretical possibility may be wholly disregarded in using the pipette. It is possible to fill the compound pipette without the aid of the long tube by manipulating so as to gradually cause the reagent to enter and then the water. When a new filling of the pipette is necessary, the reagent may easily be drawn out by means of a rubber pump.

*The ethylene pipette.* This is a special pipette devised for use with sulphuric acid (fuming) or bromine in the absorption of ethylene and the heavy hydrocarbons or fixed illuminants. It consists of a simple pipette, having three bulbs (Figure 14), the small bulb being filled with glass beads, which afford a large absorbing surface as with the Orsat apparatus, in which glass tubes were used. With the use of sulphuric acid, it is advisable to use only that which is sufficiently concentrated, to crystallize on a slight lowering of temperature. The absorbing power of acid of this strength is 8.

One passage of the gas into the pipette is usually sufficient to effect the complete absorption of the ethylene and heavy hydrocarbons. In this reaction some sulphur dioxide ($SO_2$) is usually formed, and, moreover, the vapor of fuming sulphuric acid has a very high tension, so that the gas residue before being measured, must be freed from the acid vapors in the caustic potash pipette, a single passage of the gas into the pipette sufficing. To avoid having the rubber connections between the pipette and the burette attacked by the fuming sulphuric acid, the apparatus is so put together that the sulphuric acid does not quite fill the capillary of the pipette, and the connecting capillary is allowed to remain empty; the short rubber

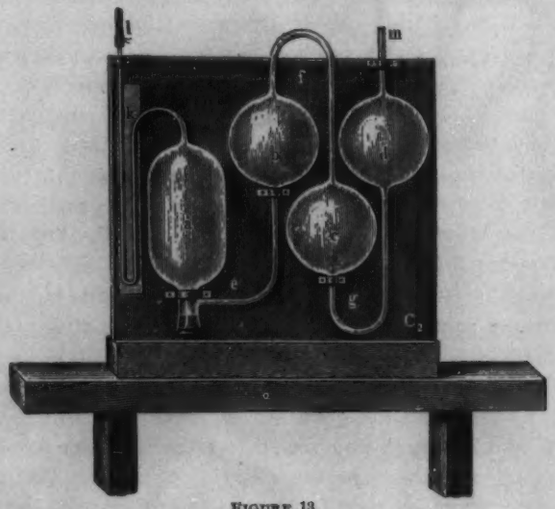


FIGURE 13.

tube of the burette is also freed from liquid by means of a narrow-tipped suction pipette, any reagent remaining in the tube being first washed out with with the same pipette. If care is taken that the sulphuric acid is stopped after the absorption at the same point in the capillary at which it stood when the burette and pipette were first put together, then the small volume of air contained in the capillary tubes in the beginning causes no error in the de-

termination of the heavy hydrocarbons or other gases, with the exception of nitrogen. In the nitrogen determination, allowance may be made for this air volume, but as each centimeter of the empty capillary corresponds to only 0.008 cubic centimeters, this value falls below the limit of unavoidable errors. After the absorption, the rubber tube is taken off from the pipette, and the capillary and larger tube are made air-tight by closing with little glass caps, which are pushed over narrow Mohr rings placed upon the tube.

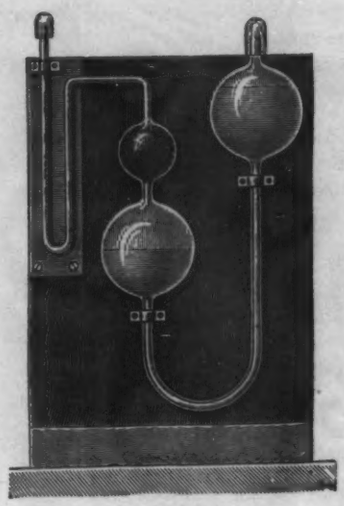


FIGURE 14.

For most purposes the bromine absorption is sufficiently accurate and far more convenient. It is also used in the pipette just described. It is not necessary to fill the pipette completely with it, being quite sufficient if a few cubic centimeters of bromine lie under water in the pipette. The bromine always remains below, there being a distinct separation of the bromine and water by reason of greater specific gravity. The water above will, however, be saturated with bromine vapor which absorbs the ethylene, etc. After this absorption, as in the case with the sulphuric acid, and as already explained in connection with the Elliott apparatus, the gas must be freed of the bromine vapor by passing it into the potassium hydroxide pipette.

(The writer is largely indebted to the work on "Methods of Gas Analysis," by Dr. W. Hemple, translated by L. H. Dennis, for the descriptions and illustrations of the Hemple apparatus.)

*(Continuation in next number.)*

# Transmission

## ALUMINUM FOR ELECTRICAL CONDUCTORS.

ALUMINUM has, for the last two or three years, been used for electrical conductors in such continually increasing amounts and with such successful results, and the desire for explicit information concerning its physical and mechanical qualities is so universal, especially in electrical transmission circles, that it has been determined to present in the following article such facts in regard to aluminum as need be known when considering its use for electrical conductors.

In comparing copper and aluminum, the following facts regarding the two metals should first be noted:

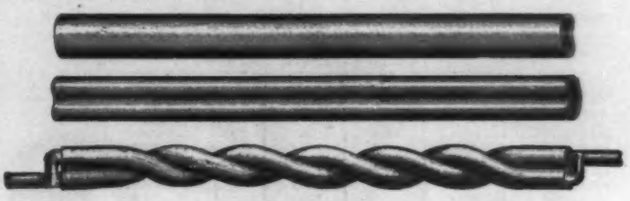
| | Aluminum. | Copper. |
|---|---|---|
| Specific Gravity - - - - - - - | 2.68 | 8.93 |
| Relative Specific Gravity - - - | 1.00 | 3.33 |
| Conductivity - - - - - - - - | 54 to 63 | 96 to 99 |

Tensile Strength per square inch, Aluminum, 24,000 to 55,000 lbs.
" " " " Copper 30,000 to 65,000 lbs.

The different grades and consequent different mechanical and electrical characteristics of both aluminum and copper make it impossible to give absolute ratios between the two metals of weight, tensile strength, price, etc., for cross-sections of equal conductivity. Unless specially mentioned, however, in this article, a conductivity of 61 for aluminum and 97 for copper will be assumed.

On account of the lower conductivity of aluminum, the cross-sections of aluminum and copper wire or bars of same resistance and same conductivity will be in the inverse ratio of their conductivities (97 : 61 :: 159 : 100); thus an aluminum wire of 159,000 circular mils area will have the same resistance as a copper wire of 100,000 circular mils area. This ratio is approximately the same as that between wires separated by one number in the Brown & Sharp gage. Thus, No. 1 aluminum wire is equivatent to No. 3 copper; No. 2 is equivalent to No. 4 copper, etc.

The comparative weights of equal volumes of aluminum and copper are as 1 for aluminum and 3.33 for copper. Therefore the relative weights of given lengths of same conductivity will be as 47.77 for aluminum to 100 for copper (159 × 1 : 100 × 3.33 :: 47.77 :



THE ALUMINUM SLEEVE-JOINT.

100); or, differently stated, the weight per mile or per thousand feet of aluminum wire is 47.77 per cent. of the weight of the same length of copper of same conductivity.

Inasmuch as it is necessary to use a larger cross-section of aluminum in order to obtain equal conductivity with copper, it is also necessary to take this increased size into consideration in determining the relative breaking loads. A load which would break a copper wire of 100,000 circular mils area would not break an aluminum wire of 159,000 circular mils area, even though the aluminum might be relatively weaker than the copper for equal sections. In order to obtain relative breaking loads, the tensile strength per square inch of aluminum should be multiplied by 159 and compared with the tensile strength per square inch of copper. Thus with an aluminum and copper wire of same conductivity, but the copper wire having a tensile strength of 50,000 pounds per square inch, and the aluminum wire only 31,446 pounds per square inch, the same actual load would be required to break either wire. (31,446 × 159 = 50,000.)

The question of price of aluminum or copper is practically a question not of price per pound but price per mile or of any given

FACTORS FOR THE DIFFERENT CONDUCTIVITIES OF ALUMINUM.

| CONDUCTIVITY OF ALUMINUM. | 63 | 62 | 61 | 60 | 59 | 58 | 57 | 56 | 55 | 54 |
|---|---|---|---|---|---|---|---|---|---|---|
| Relative cross-section (Copper equal 100) | 158. | 156.5 | 159. | 161.7 | 164.4 | 167.3 | 170.2 | 173.2 | 176.3 | 179.7 |
| Weight of aluminum, (weight of copper of equal length and equal resistance equal 100.) | 46.25 | 47. | 47.77 | 48.55 | 49.38 | 50.24 | 51.11 | 52.03 | 52.97 | 53.95 |
| Tensile Strength—Factor by which to multiply tensile strength per square inch of aluminum to obtain tensile strength per square inch required in a copper wire of equal resistance in order to secure same breaking strength | 158. | 156.5 | 159. | 161.7 | 164.4 | 167.3 | 170.2 | 173.2 | 176.3 | 179.7 |
| Price—Factor by which to multiply copper price per pound to obtain equivalent price of aluminum; also factor by which to divide aluminum price per pound to obtain equivalent price of copper | 2.16 | 2.13 | 2.1 | 2.06 | 2.03 | 1.99 | 1.96 | 1.92 | 1.89 | 1.85 |
| Price—Factor by which to divide copper price per pound to obtain equivalent price of aluminum; also factor by which to multiply aluminum price to obtain equivalent price of copper | .4625 | .47 | .4777 | .4855 | .4938 | .5024 | .5111 | .5203 | .5297 | .5395 |

TABLE I.

length. The weight per mile of aluminum is 47.77 per cent. of the weight of copper of same length and of same conductivity. Thus aluminum conductors will cost the same per mile as copper of equal conductivity if the price per pound of the copper is 47.77 per cent. of the price per pound for the aluminum. Take, for example, copper at 20 cents per pound and aluminum at 41.87 cents per pound. The cost per mile for wire of same conductivity

in either metal will be the same. (100 pounds of copper at 20 cents = $20.00; 47.77 pounds of aluminum at 41.87 cents = $20.00.)

Reduced to the form of rules, the calculations are as follows:

To obtain the aluminum price corresponding to a known copper price, divide the cost of copper per pound by .4777, or multiply by 2.1.

To obtain the copper price corresponding to a known aluminum price, multiply the cost of aluminum per pound by .4777, or divide by 2.1.

In case aluminum of conductivity other than 61 is used, the factors (.4777, 2.1 and 159) as obtained above would be somewhat changed. In Table I are given the factors for the different conductivities of aluminum as compared with 97-conductivity copper of the same resistance.

The stiffness and tensile strength of commercially pure aluminum (95.50 per cent.) is less than that of aluminum which has been alloyed with a small percentage of another metal. Thus a No. 12 B. & S. gage wire of pure aluminum will have a tensile strength of about 39,000 pounds per square inch; whereas, if alloyed with one per cent. of foreign metal, the tensile strength per square inch would be about 45,000 pounds; or, if alloyed with two per cent. of foreign metal the tensile strength would be increased to about 55,000 pounds. In sections larger than No. 12, which necessarily have had less work put upon them in rolling and drawing, the tensile strengths are not so high, but the same proportionate increases in strength are obtained by alloying. On the other hand, the conductivity of aluminum is reduced by alloying. Commercially pure aluminum has a conductivity of 63 per cent. in the Mattheissen Standard Scale. This conductivity is reduced to about 58 in a one per cent. alloy, and to about 54 in a two per cent. alloy. It is advisable, therefore, to determine just what are the requirements of each case as to conductivity and tensile strength, and to use the exact grade which will, with the minimum cross-section and consequent minimum weight, fulfill the electrical and mechanical requirements. It will be understood that it is not necessary to adhere to one or two per cent. alloys; intermediate alloys, such as three-quarters per cent., or one and one-half per cent. are made whenever required and quite as frequently as the one and two per cent. alloys.

When aluminum is used for 'bus-bars in station work, or for main circuits in electrolytic plants using large currents, the question of tensile strength does not need to be considered, for the sections used are so large that ample strength is obtained. For these purposes, therefore, aluminum of 63 per cent. conductivity can be employed, the weight of which as compared with copper of same conductivity is 46.25 per cent.

Rolled or drawn bars can be supplied in any required section and of reasonable length. Bars of approximate size of 1 × 6 inches can be rolled in lengths of about 14 feet. Bars of approximately ½ × 4 inches can be rolled in lengths of about 26 feet, and smaller bars can be made somewhat longer. For switchboard and station work, drawn bars with smooth edges and round corners are made. In the larger sizes, however, sawed or sheared edges are generally used, as drawing of these large sizes entails some additional expense.

In long distance transmission work, both good conductivity and good tensile strength are required. It is not recommended to use aluminum wire of less than 59 per cent. conductivity. If lower conductivity is used, a large wire is necessary to get a low resistance. Besides the increased cost entailed by the use of large wire, frequently the wire is of so great a diameter as to be cumbersome.

The following is an average specification for N. 2 B. & S. wire for long distance transmission work; wire to have a conductivity of 59 per cent.:

The weight is not to exceed 320 pounds per mile.

Conductivity of wire is not to be less than 59 in Mattheissen Standard Scale,

**COMPARATIVE WEIGHT AND STRENGTH OF ALUMINUM AND COPPER TELEPHONE WIRE OF EQUAL CONDUCTIVITY.**

GRADE A75 ALUMINUM WIRE, CONDUCTIVITY 58 IN THE MATTHIESSEN SCALE.

| | COPPER. | ALUMINUM. |
|---|---|---|
| Comparative section of equal conductivity, | 100 | 167 |
| Comparative weight of given lengths of equal conductivity, | 100 | 50.2 |

| COPPER. | | | ALUMINUM. | COPPER. | ALUMINUM. | ALUMINUM. | |
|---|---|---|---|---|---|---|---|
| No. | Gauge. | Diameter Inches. | Diameter Inches. | Weight per Mile. | Weight per Mile. | Tensile Strength per Square Inch. | Tensile Strength comparative to Copper of equal Conductivity. |
| 16 | B. W. G. | .0650 | .0841 | 68. | 33. | 42,000 | 70,140 |
| 14 | B. I. S. | .0800 | .1035 | 102. | 51.6 | 40,000 | 66,800 |
| 12 | B. & S. | .0808 | .1045 | 104.7 | 52.6 | 40,000 | 66,800 |
| 13 | B. I. S. | .0920 | .1190 | 135. | 68. | 38,000 | 63,460 |
| 10 | B. & S. | .1019 | .1318 | 164.3 | 83.6 | 36,000 | 60,000 |
| 12 | B. I. S. | .1040 | .1345 | 173. | 87.1 | 36,000 | 60,000 |
| 10 | B. I. S. | .1280 | .1655 | 262. | 132. | 35,000 | 58,450 |
| 8 | B. & S. | .1285 | .1662 | 264.8 | 133. | 35,000 | 58,450 |
| 10 | B. W. G. | .1340 | .1733 | 287. | 144.5 | 34,000 | 58,780 |
| 8 | B. W. G. | .1650 | .2134 | 435. | 219. | 33,000 | 55,000 |

TABLE II.

**RESISTANCE AND TENSILE STRENGTH OF ALUMINUM TELEPHONE WIRE.**

| | Grade. | Conductivity. | Comparative section of equal Conductivity, Copper at 100. | Comparative weight of given lengths of equal Conductivity, Copper at 100. |
|---|---|---|---|---|
| | A0. | 62½ | 156.4 | 47. |
| | A75 | 58 | 167. | 50.2 |
| | A2. | 54 | 180. | 54. |

| Number in B. & S. Gauge. | Diameter in Mils. | GRADE A0. | | GRADE A75. | | GRADE A2. | |
|---|---|---|---|---|---|---|---|
| | | Res. per 1,000 ft. at 75° F. | Tensile Strength. | Res. per 1,000 ft. at 75° F. | Tensile Strength. | Res. per 1,000 ft. at 75° F. | Tensile Strength. |
| 4 | 204.31 | .4012 | 27,000 | .4288 | 33,000 | .4605 | 40,000 |
| 5 | 181.94 | .5058 | 27,500 | .5408 | 34,000 | .5818 | 42,000 |
| 6 | 162.02 | .6380 | 28,000 | .6820 | 35,000 | .7325 | 44,000 |
| 7 | 144.28 | .8044 | 29,000 | .8600 | 36,000 | .9235 | 46,000 |
| 8 | 128.49 | 1.034 | 30,000 | 1.105 | 37,000 | 1.187 | 48,000 |
| 9 | 114.43 | 1.278 | 32,000 | 1.367 | 39,000 | 1.468 | 50,000 |
| 10 | 101.89 | 1.613 | 33,000 | 1.724 | 40,000 | 1.852 | 51,000 |
| 11 | 90.74 | 2.033 | 35,000 | 2.173 | 41,000 | 2.335 | 53,000 |
| 12 | 80.81 | 2.565 | 39,000 | 2.741 | 42,000 | 3.084 | 55,000 |

TABLE III.

## Table of Dimensions and Weights of Aluminum and Copper Wire.

Specific Gravity of Aluminum taken as 2.68, water weighing 62.355 pounds per cubic foot. Specific Gravity of Copper, 8.93.

| Am. Gauge, B. & S. No. | Diam. Mils. | AREA. | | WEIGHT AND LENGTH. | | | |
|---|---|---|---|---|---|---|---|
| | | Circular Mils. ($d^2$) 1 mil. = .001 inch. | Square Inch. ($d^2 \times .7854$.) | Pounds per mile, Alum'n. | Pounds per mile, Copper. | Feet per Pound Aluminum. | Feet per pound Copper. |
| 0000 | 460.000 | 211600.00 | 166190. | 1018.30 | 3393.07 | 5.185 | 1.728 |
| 000 | 409.640 | 167805.00 | 131790. | 807.52 | 2690.75 | 6.539 | 2.179 |
| 00 | 364.800 | 133079.40 | 104520. | 640.36 | 2133.74 | 8.246 | 2.748 |
| 0 | 324.860 | 105534.00 | 82886. | 507.83 | 1692.14 | 10.397 | 3.465 |
| 1 | 289.300 | 83694.20 | 65733. | 402.81 | 1342.21 | 13.108 | 4.368 |
| 2 | 257.630 | 66373.00 | 52130. | 319.44 | 1064.39 | 16.529 | 5.508 |
| 3 | 229.420 | 52634.00 | 41339. | 253.28 | 843.96 | 20.846 | 6.946 |
| 4 | 204.310 | 41742.00 | 32784. | 200.90 | 669.44 | 26.281 | 8.757 |
| 5 | 181.940 | 33102.00 | 25998. | 159.30 | 530.79 | 33.146 | 11.044 |
| 6 | 162.020 | 26250.50 | 20617. | 126.35 | 421.02 | 41.789 | 13.924 |
| 7 | 144.280 | 20816.00 | 16349. | 100.21 | 333.93 | 52.687 | 17.556 |
| 8 | 128.490 | 16509.00 | 12966. | 79.46 | 264.78 | 66.445 | 22.140 |
| 9 | 114.430 | 13094.00 | 10284. | 62.99 | 209.90 | 83.822 | 27.931 |
| 10 | 101.890 | 10381.00 | 8153.2 | 48.71 | 162.32 | 105.68 | 35.215 |
| 11 | 90.742 | 8234.00 | 6467.0 | 39.63 | 132.04 | 133.24 | 44.398 |
| 12 | 80.808 | 6529.90 | 5128.6 | 31.43 | 104.71 | 168.01 | 55.983 |
| 13 | 71.961 | 5178.40 | 4067.1 | 24.83 | 83.02 | 211.86 | 70.595 |
| 14 | 64.084 | 4106.80 | 3146.9 | 19.76 | 65.83 | 267.17 | 89.022 |
| 15 | 57.068 | 3256.70 | 2557.8 | 15.67 | 52.22 | 336.93 | 112.27 |
| 16 | 50.820 | 2582.90 | 2028.6 | 12.43 | 41.42 | 424.81 | 141.55 |
| 17 | 45.257 | 2048.20 | 1608.6 | 9.857 | 32.85 | 535.62 | 178.47 |
| 18 | 40.303 | 1624.30 | 1275.7 | 7.814 | 26.04 | 675.67 | 225.14 |
| 19 | 35.890 | 1288.10 | 1011.66 | 6.199 | 20.65 | 851.79 | 283.82 |
| 20 | 31.961 | 1021.50 | 802.28 | 4.916 | 16.38 | 1074.11 | 357.91 |
| 21 | 28.462 | 810.10 | 636.25 | 3.898 | 12.99 | 1354.65 | 451.38 |
| 22 | 25.347 | 642.70 | 504.78 | 3.091 | 10.30 | 1707.94 | 569.10 |
| 23 | 22.571 | 509.45 | 400.12 | 2.451 | 8.170 | 2153.78 | 717.66 |
| 24 | 20.100 | 404.01 | 317.31 | 1.944 | 6.478 | 2715.91 | 904.97 |
| 25 | 17.900 | 320.40 | 251.64 | 1.542 | 5.138 | 3424.66 | 1141.1 |
| 26 | 15.940 | 254.01 | 199.50 | 1.223 | 4.075 | 4317.78 | 1438.7 |
| 27 | 14.195 | 201.50 | 158.26 | .9694 | 3.230 | 5446.63 | 1814.9 |
| 28 | 12.641 | 159.79 | 125.50 | .7688 | 2.562 | 6868.13 | 2288.5 |
| 29 | 11.257 | 126.72 | 99.526 | .6098 | 2.032 | 8698.03 | 2884.9 |
| 30 | 10.025 | 100.50 | 78.933 | .4836 | 1.612 | 10917.0 | 3637.7 |
| 31 | 8.928 | 79.71 | 62.604 | .3836 | 1.278 | 13762.8 | 4585.9 |
| 32 | 7.950 | 63.20 | 49.637 | .3041 | 1.013 | 17361.1 | 5784.9 |
| 33 | 7.080 | 50.13 | 39.372 | .2412 | .8039 | 21886.7 | 7292.9 |
| 34 | 6.304 | 39.74 | 31.212 | .1912 | .6373 | 27609.1 | 9199.6 |
| 35 | 5.614 | 31.52 | 24.756 | .1517 | .5055 | 34807.3 | 11627.4 |
| 36 | 5.000 | 25.00 | 19.635 | .1203 | .4010 | 43878.9 | 14620.6 |
| 37 | 4.453 | 19.83 | 15.567 | .0954 | .3179 | 55340.4 | 18440.0 |
| 38 | 3.965 | 15.72 | 12.347 | .0757 | .2521 | 69783.7 | 23252.6 |
| 39 | 3.531 | 12.47 | 9.7939 | .0600 | .1999 | 88028.2 | 28331.9 |
| 40 | 3.144 | 9.89 | 7.7676 | .0475 | .1584 | 111099.0 | 37019.2 |

TABLE IV.

and is thus to have a resistance at 15.5 degrees Centigrade not greater than .2443 ohms per thousand feet.

The tensile strength of wire is not to be less than 29,000 pounds per square inch, and the elastic limit not less than 14,000 pounds per square inch.

The elongation of the tension test pieces by breaking is to be not less than 10 per cent. in two inches.

## Weight of Aluminum, Wro't Iron, Steel, Copper and Brass Wire.

DIAMETERS DETERMINED BY AMERICAN (BROWN & SHARPE) GAUGE.

Water at 62° Fahrenheit, 62.355 lbs. per cubic foot.

Drawn Wrought Iron is 2.8724 times heavier than Drawn Aluminum.
" Steel " 2.9322 " " " " " "
" Copper " 3.3321 " " " " " "
" Brass " 3.1900 " " " " " "

| No. of Gauge. | Size of each No. | Ft. per lb. Aluminum. | Weight of Wire Per 1000 Lineal Ft. | | | | |
|---|---|---|---|---|---|---|---|
| | | | ALUMINUM. | WR'T IRON. | STEEL. | COPPER. | BRASS. |
| | *Inch.* | *Feet.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* |
| 0000 | .46000 | 5.185 | 192.86 | 553.97 | 565.50 | 642.68 | 615.21 |
| 000 | .40964 | 6.539 | 152.94 | 439.33 | 448.45 | 509.32 | 487.92 |
| 00 | .36480 | 8.246 | 121.28 | 348.40 | 355.65 | 404.20 | 386.94 |
| 0 | .32486 | 10.396 | 96.18 | 276.30 | 282.02 | 320.50 | 306.83 |
| 1 | .28930 | 13.108 | 76.29 | 219.11 | 223.68 | 254.20 | 243.35 |
| 2 | .25763 | 16.529 | 60.50 | 173.78 | 177.38 | 201.60 | 192.98 |
| 3 | .22942 | 20.846 | 47.97 | 137.80 | 140.67 | 159.86 | 153.02 |
| 4 | .20431 | 26.281 | 38.05 | 109.28 | 111.57 | 126.78 | 121.37 |
| 5 | .18194 | 33.146 | 30.17 | 86.68 | 88.46 | 100.54 | 96.26 |
| 6 | .16202 | 41.789 | 23.93 | 68.73 | 70.15 | 79.72 | 76.32 |
| 7 | .14428 | 52.687 | 18.98 | 54.43 | 55.56 | 63.23 | 60.53 |
| 8 | .12849 | 66.445 | 15.05 | 43.23 | 44.12 | 50.14 | 48.00 |
| 9 | .11443 | 83.822 | 11.93 | 34.28 | 34.99 | 39.77 | 38.07 |
| 10 | .10189 | 105.68 | 9.462 | 27.18 | 27.74 | 31.53 | 30.18 |
| 11 | .090742 | 133.24 | 7.505 | 21.56 | 22.01 | 25.01 | 23.94 |
| 12 | .080808 | 168.01 | 5.952 | 17.10 | 17.46 | 19.83 | 18.99 |
| 13 | .071961 | 211.86 | 4.720 | 13.56 | 13.84 | 15.73 | 15.06 |
| 14 | .064084 | 267.17 | 3.743 | 10.75 | 10.98 | 12.47 | 11.94 |
| 15 | .057068 | 336.93 | 2.968 | 8.526 | 8.704 | 9.890 | 9.468 |
| 16 | .050820 | 424.81 | 2.354 | 6.761 | 6.903 | 7.843 | 7.508 |
| 17 | .045257 | 535.62 | 1.867 | 5.362 | 5.474 | 6.220 | 5.955 |
| 18 | .040303 | 675.67 | 1.480 | 4.252 | 4.342 | 4.933 | 4.723 |
| 19 | .035890 | 851.79 | 1.174 | 3.372 | 3.443 | 3.912 | 3.755 |
| 20 | .031961 | 1074.11 | .9310 | 2.672 | 2.730 | 3.102 | 2.970 |
| 21 | .028462 | 1354.65 | .7382 | 2.121 | 2.165 | 2.460 | 2.355 |
| 22 | .025347 | 1707.94 | .5855 | 1.682 | 1.717 | 1.951 | 1.868 |
| 23 | .022571 | 2153.78 | .4643 | 1.333 | 1.361 | 1.547 | 1.481 |
| 24 | .020100 | 2715.91 | .3682 | 1.058 | 1.080 | 1.227 | 1.175 |
| 25 | .017900 | 3424.66 | .2920 | .8388 | .8563 | .9731 | .9316 |
| 26 | .015940 | 4317.78 | .2316 | .6652 | .6791 | .7716 | .7387 |
| 27 | .014195 | 5446.63 | .1836 | .5276 | .5385 | .6120 | .5858 |
| 28 | .012641 | 6868.13 | .1456 | .4183 | .4270 | .4853 | .4645 |
| 29 | .011257 | 8098.03 | .1155 | .3317 | .3386 | .3849 | .3683 |
| 30 | .010025 | 10917.0 | .0916 | .2631 | .2686 | .3052 | .2922 |
| 31 | .008928 | 13762.8 | .0727 | .2087 | .2130 | .2421 | .2318 |
| 32 | .007950 | 17361.1 | .0576 | .1655 | .1603 | .1919 | .1837 |
| 33 | .007080 | 21886.7 | .0457 | .1312 | .1340 | .1522 | .1457 |
| 34 | .006304 | 27609.1 | .0362 | .1040 | .1062 | .1207 | .1155 |
| 35 | .005614 | 34807.3 | .0287 | .0825 | .0842 | .0957 | .0916 |
| 36 | .005000 | 43873.9 | .0228 | .0655 | .0668 | .0759 | .0727 |
| 37 | .004453 | 55340.4 | .0181 | .0519 | .0530 | .0602 | .0577 |
| 38 | .003965 | 69783.7 | .0143 | .0413 | .0420 | .0478 | .0457 |
| 39 | .003531 | 88028.2 | .0114 | .0326 | .0333 | .0379 | .0363 |
| 40 | .003144 | 111099.0 | .0090 | .0259 | .0264 | .0300 | .0287 |
| Specific Gravity Wire..... | | | 2.680 | 7.698 | 7.858 | 8.930 | 8.549 |
| Weight per cubic foot, Wire ... | | | 167.111 | 480.000 | 490.000 | 556.830 | 533.073 |

TABLE V.

Wrapping test: Wire shall be capable of being wrapped in six turns around its own diameter, unwrapped, and again wrapped in six turns around its own diameter in the same direction as the first wrapping, without showing any cracks.

The wire is to be packed in coils 18 to 24 inches internal diameter. No joints will be permitted in any coil. Coils must not weigh less than 80 pounds each. Each coil must be securely tied with aluminum wire protected by burlap writing.

In case a No. 2 wire of 62 conductivity were wanted, the specifications as given above would be changed in the following points:

Conductivity of the wire is not to be less than 62 in Mattheissen Standard Scale and is thus to have a resistance at 15.5 degrees Centigrade, not greater than .2443 ohms per thousand feet.

The tensile strength of wire is not to be less than 23,000 pounds per square inch and the elastic limit not less than 11,000 pounds per square inch.

The elongation of the tension test pieces by breaking is to be not less than nine per cent. in two inches.

On account of the small sizes of wire used for telephone and telegraph purposes the breaking of the wire is to be specially guarded against in some instances. In such cases a wire of a slightly reduced conductivity but high tensile strength is used, the low conductivity being in most cases not objectionable, inasmuch as the conductivity is not so materially reduced as to interfere with the successful working of the wire.

For telephone and telegraph wires, the Pittsburg Reduction Company makes three grades: AO, A75 and A2, and in Table II is given the characteristics of grade A75 of these three grades, while Table III gives the resistance and tensile strength of the three grades of telephone wires.

The soldering of solid wire is not recommended. Small wires can be joined by twisting the ends around each other as is usually done in telephone and telegraph work. Aluminum sleeve joints either of tubes or rolled up sheet can be obtained from manufacturers who make such joints in copper for joining copper wire. For large sizes of aluminum wire where twisting the ends together is impossible, these mechanical joints give a strong and satisfactory connection. Joints of this kind are easily and quickly made; they possess mechanical strength equal to that of the wire itself, and the conductivity is equal to that of an equal length of the wire. The extended area of the contact surfaces, the force by which the surfaces are held together, and their protection from corrosion insure a permanent joint. Cables are best joined by soldering the ends in a brass or aluminum sleeve the same as is done with copper cables.

Cables of any size required are now on the market, and concentric laid cables up to a total of 127 wires, and $7 \times 7$ cables are made. Aluminum cables are used for street railway feeders and for all other places where copper cables have been heretofore used. It is seldom that so small a cable is used that the tensile strength of pure aluminum is not sufficient. Usually, therefore, cables are made of 63 or 62 conductivity wire, although if required, the the stronger grade wire can be used. Wire and cables with weatherproof insulation are also regularly supplied, and if required, arrangements can be made for covering aluminum wire with any other variety of insulation. Reference may be made to Tables VIII and IX for weights of these insulated wires and cables.

Soft annealed wire for tying line at insulators is made. It is

## TABLE OF RESISTANCES OF PURE COPPER WIRE.*

| Am. Gauge, B. & S. No. | Resistance at 75° F. | | | | Log $d^2$. | Log $R$. |
|---|---|---|---|---|---|---|
| | R. Ohms per 1000 Feet. | Ohms per mile. | Feet per Ohm. | Ohms per lb. | | |
| 0000 | .04906 | .25903 | 20383. | .000076736 | 5.3255157 | 7.6907235 |
| 000 | .06186 | .32664 | 16165. | .00012039 | 5.2248000 | 7.7914392 |
| 00 | .07801 | .41187 | 12820. | .00019423 | 5.1241128 | 7.8921264 |
| 0 | .09831 | .51909 | 10409. | .00030772 | 5.0236310 | 7.9926082 |
| 1 | .12404 | .65490 | 8062.3 | .00048994 | 4.9229353 | 7.0935439 |
| 2 | .15640 | .82582 | 6393.7 | .00078045 | 4.8219914 | 7.1942478 |
| 3 | .19723 | 1.0414 | 5070.2 | .0012406 | 4.7212664 | 7.2949728 |
| 4 | .24869 | 1.3131 | 4021.0 | .0019721 | 4.6205733 | 7.3956659 |
| 5 | .31361 | 1.6558 | 3188.0 | .0031361 | 4.5198542 | 7.4963850 |
| 6 | .39546 | 2.0881 | 2528.7 | .0049868 | 4.4191300 | 7.5971092 |
| 7 | .49871 | 2.6331 | 2005.2 | .0079294 | 4.3183973 | 7.6978419 |
| 8 | .62881 | 3.3201 | 1590.3 | .012608 | 4.2177208 | 7.7985184 |
| 9 | .79281 | 4.1860 | 1261.3 | .020042 | 4.1170723 | 7.8991669 |
| 10 | 1. | 5.2800 | 1000.0 | .031380 | 4.0162392 | 0.0000000 |
| 11 | 1.2607 | 6.6568 | 793.18 | .050682 | 3.9156109 | 0.1006283 |
| 12 | 1.5898 | 8.3940 | 629.72 | .080585 | 3.8149855 | 0.2013327 |
| 13 | 2.0047 | 10.585 | 498.83 | .12841 | 3.7141966 | 0.3020436 |
| 14 | 2.5908 | 13.680 | 385.97 | .20880 | 3.6135004 | 0.4134415 |
| 15 | 3.1150 | 16.477 | 321.02 | .31658 | 3.5127778 | 0.4934614 |
| 16 | 4.0191 | 21.221 | 248.81 | .51501 | 3.4121076 | 0.6041316 |
| 17 | 5.0683 | 26.761 | 197.30 | .81900 | 3.3113724 | 0.7048668 |
| 18 | 6.3911 | 33.745 | 156.47 | 1.3023 | 3.2106662 | 0.8055730 |
| 19 | 8.2889 | 43.765 | 120.64 | 2.1904 | 3.1099462 | 0.9184861 |
| 20 | 10.163 | 53.658 | 98.401 | 3.2926 | 3.0092384 | 1.0070008 |
| 21 | 12.815 | 67.660 | 78.037 | 5.2355 | 2.9085386 | 1.1077006 |
| 22 | 16.152 | 85.263 | 61.911 | 8.3208 | 2.8080083 | 1.2082306 |
| 23 | 20.377 | 107.59 | 49.087 | 13.238 | 2.7071016 | 1.3091371 |
| 24 | 25.695 | 135.67 | 38.918 | 21.050 | 2.6063921 | 1.4098477 |
| 25 | 32.400 | 171.07 | 30.864 | 33.466 | 2.5056925 | 1.5105464 |
| 26 | 40.868 | 215.79 | 24.469 | 35.235 | 2.4048508 | 1.6113881 |
| 27 | 51.519 | 272.02 | 19.410 | 84.644 | 2.3042751 | 1.7119646 |
| 28 | 64.966 | 343.02 | 15.393 | 134.56 | 2.2035496 | 1.8126899 |
| 29 | 81.921 | 432.54 | 12.207 | 213.96 | 2.1028452 | 1.9133940 |
| 30 | 103.30 | 545.39 | 9.6812 | 340.25 | 2.0021661 | 2.0140731 |
| 31 | 127.27 | 671.99 | 7.8574 | 528.45 | 1.9015128 | 2.1047264 |
| 32 | 164.26 | 867.27 | 6.0890 | 860.33 | 1.8007171 | 2.2156221 |
| 33 | 207.08 | 1093.4 | 4.8290 | 1367.3 | 1.7000977 | 2.3151415 |
| 34 | 261.23 | 1379.3 | 3.8281 | 2175.5 | 1.5992279 | 2.4170113 |
| 35 | 329.35 | 1738.9 | 3.0363 | 3458.5 | 1.4985862 | 2.5176530 |
| 36 | 415.24 | 2192.5 | 2.4081 | 5497.4 | 1.3979400 | 2.6182992 |
| 37 | 523.76 | 2765.5 | 1.9093 | 8742.1 | 1.2971037 | 2.7191355 |
| 38 | 660.37 | 3486.7 | 1.5143 | 13772. | 1.1964525 | 2.8197867 |
| 39 | 832.48 | 4395.5 | 1.2012 | 21896. | 1.0958665 | 2.9203727 |
| 40 | 1049.7 | 5542.1 | .9527 | 34823. | 0.9951963 | 3.0210429 |

*Calculated on the basis of Dr. Matthiessen's standard, viz.: 1 mile of pure copper wire of 1-16 inch diameter equals 13.59 Ohms at 15.5° C. or 59.9° Fahr.

TABLE VI.

especially recommended to use this annealed tie wire, for an aluminum line tied with too hard wire will become dented and consequently will break with less strain than if the cross-section had been unimpaired.

The co-efficient of expansion of aluminum is .0000231; therefore, in stringing aluminum wires at ordinary temperatues, a little greater deflection should be allowed.

In this connection it should be borne in mind that with aerial lines the snow and ice load is practically as heavy on small wire as on larger sections, so that no objection can be raised on this score against the use of aluminum on account of its larger section.

Aluminum is not acted upon in dry air and the corrosion in moist air is by the formation of the oxide of aluminum—alumnia, a harmless salt which forms an impenetrable coating on the metal and protects it from corrosion to a considerable extent. Ammonia solutions act only upon the surface of aluminum, forming a coating which resists corrosion from dilute mineral acids, dilute solutions of organic acids, as well as moist and dry air. Sulphurous acids, such as locomotive flue gases, etc., will have no effect on aluminum.

Aluminum is reduced by electrolytic methods from an ore that is practically free from impurities. Thus, aluminum as it is reduced, is almost chemically pure and absolutely uniform in composition. In this respect it has the advantage over all other common metals which are reduced from impure ores and are necessarily not uniform in chemical composition.

The following statements, which are in accord with the opinions of electricians who have given these questions careful study, refer to the relative properties of aluminum and copper wire of equal conductivity when used in the transmission of alternating currents:

## TABLE OF RESISTANCES OF PURE ALUMINUM WIRE.*

Pure aluminum weighs 167.111 pounds to the cubic foot. The conductivity of pure aluminum is 60% of the conductivity of pure copper.

| Am. Gauge, B. & S. No. | Resistance at 75° F. R Ohms 1000 Ft. | Ohms per mile. | Feet per Ohm. | Ohms per lb. | Log $d^2$. | Log $R$. |
|---|---|---|---|---|---|---|
| 0000 | .08177 | .43172 | 12229.8 | .00042714 | 5.3255157 | 5.912594 |
| 000 | .10310 | .54440 | 9699.0 | .00067022 | 5.2248900 | 1.013259 |
| 00 | .13001 | .68645 | 7692.0 | .00108116 | 5.1241128 | 1.113977 |
| 0 | .16385 | .86515 | 6245.4 | .0016739 | 5.0236310 | 1.219715 |
| 1 | .20672 | 1.09150 | 4637.35 | .0027272 | 4.9226953 | 1.315382 |
| 2 | .26077 | 1.37637 | 3836.22 | .0043441 | 4.8219914 | 1.416258 |
| 3 | .32872 | 1.7357 | 3036.12 | .0069057 | 4.7212664 | 1.516826 |
| 4 | .41448 | 2.1885 | 2412.60 | .0109773 | 4.6205733 | 1.617504 |
| 5 | .52268 | 2.7597 | 1913.22 | .017456 | 4.5198542 | 1.718236 |
| 6 | .65610 | 3.4802 | 1517.22 | .027758 | 4.4191300 | 1.818951 |
| 7 | .83118 | 4.3885 | 1203.12 | .044138 | 4.3183973 | 1.919605 |
| 8 | 1.06802 | 5.5355 | 964.18 | .070179 | 4.2177208 | 0.028579 |
| 9 | 1.32135 | 6.9767 | 756.78 | .111561 | 4.1170723 | 0.121018 |
| 10 | 1.66667 | 8.8000 | 600.00 | .17467 | 4.0162392 | 0.221849 |
| 11 | 2.1012 | 11.0947 | 475.908 | .28211 | 3.9156109 | 0.322467 |
| 12 | 2.6497 | 13.9900 | 377.412 | .44856 | 3.8149065 | 0.423197 |
| 13 | 3.3412 | 17.642 | 299.298 | .71478 | 3.7141956 | 0.523902 |
| 14 | 4.3180 | 22.800 | 231.582 | 1.16225 | 3.6135004 | 0.635283 |
| 15 | 5.1917 | 27.402 | 192.612 | 1.7600 | 3.5127778 | 0.715310 |
| 16 | 6.6985 | 35.368 | 149.286 | 2.8667 | 3.4121076 | 0.825978 |
| 17 | 8.4472 | 44.602 | 118.380 | 4.5588 | 3.3113724 | 0.926713 |
| 18 | 10.6518 | 56.242 | 93.882 | 7.2490 | 3.2106662 | 1.027423 |
| 19 | 13.8148 | 72.942 | 72.384 | 12.1916 | 3.1099462 | 1.140345 |
| 20 | 16.938 | 89.430 | 59.0406 | 18.328 | 3.0092384 | 1.228862 |
| 21 | 21.358 | 112.767 | 46.8222 | 29.142 | 2.9085386 | 1.329561 |
| 22 | 26.920 | 142.138 | 37.1466 | 46.316 | 2.8080083 | 1.430075 |
| 23 | 33.962 | 179.32 | 29.4522 | 73.686 | 2.7071016 | 1.531006 |
| 24 | 42.825 | 226.12 | 23.3508 | 117.170 | 2.6063921 | 1.631697 |
| 25 | 54.000 | 285.12 | 18.5184 | 186.28 | 2.5056925 | 1.732394 |
| 26 | 68.113 | 359.65 | 14.6814 | 296.32 | 2.4048508 | 1.833230 |
| 27 | 85.865 | 453.37 | 11.6460 | 485.56 | 2.3042751 | 1.933816 |
| 28 | 108.277 | 571.70 | 9.2358 | 749.02 | 2.2035496 | 2.034536 |
| 29 | 136.535 | 720.90 | 7.3242 | 1190.97 | 2.1028452 | 2.135244 |
| 30 | 172.17 | 908.98 | 5.8087 | 1893.9 | 2.0021661 | 2.235957 |
| 31 | 212.12 | 1119.98 | 4.7144 | 2941.5 | 1.9015128 | 2.326582 |
| 32 | 273.97 | 1445.45 | 3.6528 | 4788.9 | 1.8007171 | 2.437703 |
| 33 | 345.13 | 1822.3 | 2.8974 | 7610.7 | 1.7000977 | 2.537963 |
| 34 | 435.38 | 2296.8 | 2.2969 | 12109.4 | 1.5992279 | 2.638868 |
| 35 | 548.92 | 2898.2 | 1.8218 | 19251. | 1.4985862 | 2.729508 |
| 36 | 692.07 | 3654.2 | 1.4449 | 30600. | 1.3979400 | 2.840150 |
| 37 | 872.93 | 4609.2 | 1.1456 | 48661. | 1.2971037 | 2.940979 |
| 38 | 1100.62 | 5811.2 | .9086 | 76658. | 1.1964525 | 3.041638 |
| 39 | 1387.47 | 7325.8 | .7207 | 121881. | 1.0958665 | 3.142224 |
| 40 | 1749.50 | 9236.8 | .5716 | 193835. | 0.9951963 | 3.242914 |

*Calculated on the basis of Dr. Matthiessen's standard, viz.: 1 mile of pure copper wire of $\frac{1}{17}$ inch diameter equals 13.50 ohms at 15.5° C. or 59.9° Fahr.

TABLE VII.

## STRANDED ALUMINUM WIRE.

### DIAMETER AND PROPERTIES.

CONDUCTIVITY AT 62 IN THE MATTHIESSEN STANDARD SCALE.

| Number B. & S. Gauge. | Circular Mils. | Diameters. Decimal Parts of an Inch. | Diameters. Nearest 32nd of an Inch. | Weight in Pounds. Bare. Per 1,000 Feet | Bare. Per Mile. | Triple Braid Insulated. Per 1,000 Feet | Resistance in Ohms at 75° F. per 1,000 Feet |
|---|---|---|---|---|---|---|---|
| ..... | 1000000 | 1.152 | 1 1/16 | 980 | 4900 | 1400 | .08625 |
| ..... | 950000 | 1.125 | 1 1/16 | 974 | 4617 | 1340 | .09733 |
| ..... | 900000 | 1.092 | 1 1/16 | 925 | 4374 | 1270 | .09891 |
| ..... | 850000 | 1.062 | 1 1/16 | 782 | 4130 | 1201 | .04989 |
| ..... | 800000 | 1.030 | 1 1/16 | 736 | 3889 | 1135 | .05282 |
| ..... | 750000 | .990 | 1 | 690 | 3645 | 1067 | .05722 |
| ..... | 700000 | .953 | 15/16 | 644 | 3402 | 1001 | .07302 |
| ..... | 650000 | .927 | 15/16 | 598 | 3159 | 930 | .07575 |
| ..... | 600000 | .891 | 15/16 | 552 | 2916 | 878 | .07789 |
| ..... | 550000 | .865 | 7/8 | 506 | 2673 | 806 | .08044 |
| ..... | 500000 | .810 | 13/16 | 460 | 2430 | 749 | .08347 |
| ..... | 450000 | .770 | 13/16 | 414 | 2187 | 685 | .08739 |
| ..... | 400000 | .728 | 3/4 | 368 | 1944 | 567 | .09184 |
| ..... | 350000 | .679 | 11/16 | 322 | 1701 | 502 | .04782 |
| ..... | 300000 | .630 | 5/8 | 276 | 1458 | 435 | .0536 |
| ..... | 250000 | .590 | 5/8 | 230 | 1215 | 375 | .06368 |
| 0000 | 211600 | .550 | 9/16 | 195 | 1028 | 290 | .07242 |
| 000 | 167800 | .470 | 1/2 | 155 | 818 | 232 | .09064 |
| 00 | 133079 | .430 | 7/16 | 122 | 647 | 182 | .10903 |
| 0 | 105534 | .375 | 3/8 | 97 | 513 | 135 | .1364 |
| 1 | 83694 | .330 | 5/16 | 77 | 407 | 122 | .1664 |
| 2 | 66373 | .306 | 5/16 | 61 | 321 | 109 | .2543 |
| 3 | 52634 | .283 | 5/16 | 48.5 | 256 | 89 | .3182 |
| 4 | 41742 | .238 | 1/4 | 38.5 | 203 | 72 | .4012 |

TABLE VIII.

The self-induction in a circuit is less with large wire than with small ones, and it is decreased when the wires are placed closer together. If the wires are the same distance apart in both cases, then the self-induction will be less in an aluminum circuit than in a copper circuit, and the resulting drop in voltage in the line will be less; though the difference is usually quite small, it is in favor of aluminum. If the distance between the wires in an aluminum circuit is 25 per cent. greater than in a copper circuit the self-induction will be the same in the two cases. The separation of the wires is sometimes desirable, especially if spans are increased in length.

The induction in one circuit caused by "transformer action" from current in an adjacent circuit is the same whether either

## TABLE OF WEIGHTS OF WEATHERPROOF ALUMINUM WIRE.

| Number B. & S. Gauge. | Triple Braid. Weight per 1,000 Feet. | Triple Braid. Weight per Mile. | Double Braid. Weight per 1,000 Feet. | Double Braid. Weight per Mile. |
|---|---|---|---|---|
| 0000 | 284 | 1497 | 266 | 1402 |
| 000 | 234 | 1235 | 218 | 1151 |
| 00 | 195 | 1031 | 169 | 893 |
| 0 | 162 | 856 | 127 | 671 |
| 1 | 131 | 694 | 103 | 546 |
| 2 | 110 | 581 | 90 | 475 |
| 3 | 89 | 470 | 74 | 390 |
| 4 | 72 | 380 | 62 | 327 |
| 5 | 63 | 333 | 55 | 291 |
| 6 | 56 | 294 | 45 | 236 |
| 8 | 37 | 196 | 35 | 186 |
| 10 | 29 | 154 | 23 | 122 |
| 12 | 19 | 101 | 16 | 86 |
| 14 | 16 | 86 | 11 | 60 |
| 16 | 10 | 50 | 8 | 40 |
| 18 | 8 | 40 | 7 | 35 |

TABLE IX.

or both are copper, provided the wires maintain the same relative positions in all cases. As the effect of mutual induction is neutralized by transposition of the wires of one circuit it is usually eliminated entirely. Mutual induction is therefore no factor whatever in the choice between aluminum and copper.

An alternating current does not flow uniformly in a conductor as there is a greater density near the surface. The increase in wires less than one-half or three-quarters of an inch in diameter is so slight as to be negligible and it is the same for the aluminum and the copper conductors of equal conductivity.

The quantity of heat produced in two wires being the same, the increase in temperature will be greater in the wire having less surface. The copper wire will therefore heat more than the aluminum wire. The increased temperature will in turn increase the resistance, so that if the wires were of equal resistance when carrying no current the resistance of the copper wire will be greater when the wires carry equal currents. This difference is slight, but it is in favor of aluminum.

The capacity in a circuit is greater with large wires than with small wires, and the charging current in an aluminum circuit is consequently greater than in a corresponding copper circuit if the wires are the same distance apart in the two cases. The difference is not great: about 10 per cent. The charging current is often too small to be of any consequence, and it is useful in neutralizing the lagging current caused by self-induction in load and circuit. The slight difference between aluminum and copper is therefore usually in favor of the former.

Acknowledgement must be made to the Pittsburg Reduction Company, manufacturers of aluminum, and to John Martin, its Pacific Coast agent, for the valuable information and tables presented herewith.

## Fraternal

### CONVENTION OF THE TRANSMISSION ASSOCIATION.

THE Third Annual Convention of the Pacific Coast Electric Transmission Association was held at the Cliff House, San Francisco, on June 20-21, and was signalized by its large attendance and by the especial value of its papers and the liberality of the discussions of them. During the first day the convention was presided over by W. Frank Pierce, President, and among the full or associate members present were the following corporations by duly accredited representatives:

Blue Lakes Water Company, San Francisco, Cal.
Central California Electric Company, Sacramento, Cal.
General Electric Company, San Francisco, Cal.
Nevada County Electric Power Company, Nevada City, Cal.
Power Development Company, Bakersfield, Cal.
Roeblings' Sons' Company, The John A., San Francisco, Cal.
Sacramento Electric, Gas and Railway Company, Sacramento, Cal.
Salt Lake City Water and Electric Power Company, Salt Lake City, Utah.
Standard Electric Company of California, San Francisco, Cal.
Washburn & Moen Manufacturing Company, San Francisco, Cal.
Westinghouse Electric and Manufacturing Company, San Francisco, Cal.
Yuba Power Company, San Francisco, Cal.

Among the individuals who attended the convention were noted:

Angus, Wm., secretary The Pacific Syndicate, San Francisco, Cal.
Adams, Frank P., superintendent Stockton Gas and Electric Company, Stockton, Cal.
Barbour, F. F., manager Power and Mining Department, General Electric Company, San Francisco, Cal.
Beal, C. N., secretary and treasurer Power Development Company, Bakersfield, Cal.
Bowie, A. J., Jr., electrical engineer, San Francisco, Cal.
Bullock, T. S., general manager Sierra Railway Company, Jamestown, Cal.
Cory, Prof. C. L., professor of electrical engineering, University of California, Berkeley, Cal.
Edgar, W. H., Dearborn Drug and Chemical Works, Chicago, Ill.
Elder, R. B., Westinghouse Electric and Manufacturing Company, San Francisco, Cal.
Ellis, Geo. B., vice-president Redlands Electric Light and Power Company, Redlands, Cal.
Gilbert, C. P, general manager Standard Electric Company of California, San Francisco, Cal.
Heger, W. S., manager Westinghouse Electric and Manufacturing Company, San Francisco, Cal.
Hicks, Lewis A., C. E., Kern County Land Company, Bakersfield, Cal.
Hitzroth, L. D., assistant superintendent San Francisco Gas and Electric Company, San Francisco, Cal.
Hutton, C. Wm., electrical engineer Sacramento Electric Railway and Gas Company, Sacramento, Cal.
Jones, R. M., electrical engineer Salt Lake City Water and Electric Power Company, Salt Lake City, Utah.
Keith, Dr. N. S., electrical engineer, San Francisco, Cal.
Lamson, A. G., president Salt Lake City Water and Electric Power Company, Salt Lake City, Utah.
Lee, F. V. T., manager Pacific Coast agencies for Fred M. Locke, Pittsburg Reduction Company, and the Stanley Electric Manufacturing Company, San Francisco, Cal.
Low, Geo. P., editor and proprietor THE JOURNAL OF ELECTRICITY, POWER AND GAS, San Francisco, Cal.
Martin, John, president Yuba Electric Company, and Pacific Coast agent for Fred M. Locke, Pittsburg Reduction Company, and the Stanley Electric Manufacturing Company, San Francisco, Cal.
Mason-Gardiner, John, hydraulic engineer, Los Angeles, Cal.
Masson, R. S., superintendent Independent Electric Light and Power Company, San Francisco, Cal.
Mortimer, J. D., University of California, Berkeley, Cal.
Perrine, Dr. F. A. C., electrical engineer Standard Electric Company of California, San Francisco, Cal.
Pierce, W. Frank, president Blue Lakes Water Company, San Francisco, Cal.
Poniatowski, Pce. A., president Standard Electric Company of California, San Francisco, Cal.
Scribner, H. D., agent Westinghouse Electric and Manufacturing Company, San Francisco, Cal.
Sharp, E. C., John A. Roeblings' Sons' Company, San Francisco, Cal.
Sloan, Chas. F., Pacific Coast agent Hemingway Glass Company, Pass & Seymour, and the Standard Underground Cable Company, San Francisco, Cal.
Van Norden, Dr. Chas., president Central California Electric Company, Sacramento, Cal.
Wallis, G. H., Washburn & Moen Manufacturing Company, San Francisco, Cal.

In this issue of the JOURNAL is presented four of the six papers constituting those read during the two days' session of the convention, and the titles of the papers, with their authors, are:

"Tests and Calculations for a Forty-Mile Aluminum Transmission Line," by Dr. F. A. C. Perrine.
"Electric Lighting versus Gas," by John Martin.
"Hints on Long-Distance Transmission," by R. W. Van Norden.
"On the Determination of a Fair Return for Current Supply," by C. Wm. Hutton.
"Regulation of Alternating-Current Machinery," by Prof. C. L. Cory.
"Electrically-Driven Centrifugal Pumps," by L. A. Hicks.

As stated, these papers were freely discussed, as will appear in the report of the transactions of the Association to be presented in the next number of the JOURNAL.

During the executive meeting of the Association, held in the afternoon of the first day, the following corporations were elected to full membership:

Butte County Electric Power Company, Chico, Cal.
Kern, Rand Company, Los Angeles, Cal.
Redlands Light and Power Company, Redlands, Cal.
Snoqualmie Falls Power Company, Seattle, Wash.

The following were elected to associate membership:

San Francisco Gas and Electric Company, San Francisco.
Wagner Electric Manufacturing Company, St. Louis, Mo.

The Association also, in its executive session, elected Prof. C. L. Cory, of the University of California, to honorary membership.

The election of officers for the year 1899-1900, which was held during the executive session, resulted in the election of Pce. A. Poniatowski, President; A. G. Lamson, Vice-President; Geo. P Low, Secretary, and Wm. Angus, Treasurer. The Executive Committee for the ensuing term is to consist of the president, *ex-officio*, and Messrs. Gilbert and Beal.

The social functions of the convention consisted of a banquet given by the Association at the conclusion of the afternoon session of the first day's proceedings. Covers were laid for fifty guests; the repast was spiced with the fun and merriment of many after-dinner speeches, and the occasion was most enjoyable.

One of the many good results of which the great success of the Third Annual Convention has been prolific, has been the determination to hold at least quarterly, or perhaps bi-monthly, meetings of the Association in the future, due announcement of which, together with full reports of their proceedings, will be made in these columns.

## Literature.

ELECTRICAL AND MECHANICAL VEST-POCKET MANUAL, by Sidney Sprout, E. E. Size, 2¾x5 inches; leather, round corners and gilt edges; 204 pages. Published by Sprout & Stevens, 519 Emma Spreckels Building, San Francisco. Price, $1.00.

Of the many engineers' hand-books placed upon the market in recent years, the "Electrical and Mechanical Vest-Pocket Manual" is certainly the most complete and comprehensive. Its 204 pages are filled with information of the utmost value to electricians, engineers, and mechanics in general. The author has compiled a mass of tables and data never before published, and new indeed must be the problem not touched upon by this little book. Calculations for almost the entire field of engineering are to be found within its covers, and the book is indexed in such a perfect manner that it is but the work of a moment to find any desired subject. The "Manual" will undoubtedly be eagerly sought for by engineers.

## Industrial

*In Responding to Advertisements in this Publication, please mention "The Journal of Electricity."*

### PREPARE FOR THE HOT WEATHER.

The use of fan motors during the summer months has become a necessity wherever a central station renders the use of such a convenience possible. The discomforts of the heated season are, in a large measure, overcome wherever fan motors have been introduced.

The Sprague-Lundell Fan Motor, '99 model, more than upholds the reputation which this class of goods has made for the Sprague Electric Company. For several years this company has been turning out high-class electrical machinery, claiming that a finished machine at a reasonable price would win more favor than a cheaply constructed affair which would sell at a low figure and last but a single season. The truth of this contention has been more than demonstrated. The Sprague-Lundell fans have been adopted by the United States Government for use on the transports, and statistics prove their efficiency.

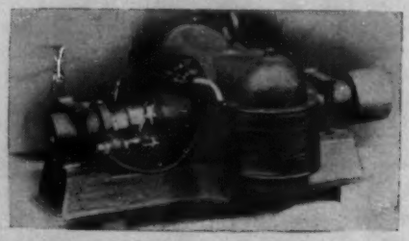
The Brooks-Follis Electric Corporation, western agents for the Sprague Electric Company, is fully prepared to meet any demands which may be made upon it for Sprague material, their storerooms at 523-525 Mission street, San Francisco, being handsomely stocked with fan and power motors and ceiling fans.

The Brooks-Follis company also handles the lamps of the Fostoria Incandescent Lamp Company. The Fostoria lamp has demonstrated its many good qualities and is in general use throughout the coast. The popularity of this lamp has induced the Brooks-Follis Electric Corporation to carry a full stock at their storerooms in connection with electrical apparatus of every description necessary for construction and maintenance of light and power plants.

### THE KASTEN SLOW-SPEED MOTOR.

Messrs. Ferdinand Kasten & Company, 519 Howard street, San Francisco, are bringing out a line of slow-speed bi-polar motors which are meeting with a ready sale. As seen from the half-tone engraving presented below, which is of a one-horsepower motor, there is nothing especially new or original in the general design of the machine. It is of the familiar Manchester type of field and frame, but by using the best of materials, strictly first-class workmanship and correct proportions, the manufacturers have been able to reduce the speed to a remarkable degree below that ordinarily used in motors of this size.

The one-horsepower motor illustrated weighs only 160 pounds and runs at 1000 revolutions per minute, and its efficiency is guaranteed by the makers to be 75 per cent. The sizes of the Kasten dynamos from ten-horsepower up are of the multipolar type, and



the 15-horsepower motor runs at 650 revolutions per minute and with a claimed efficiency of 90 per cent. The armatures of all sizes of machines are slotted, and carbon brushes are used, which run absolutely without sparking; the machines have self-oiling bearings and they require no attention whatever.

One of the interesting novelties brought out by the company is the Kasten motor-starting box, which is so arranged that through its use a motor may be controlled from any number of points by push buttons with auxiliary circuits, or by derived line currents as in the Sechrist automatic switch. The Kasten device possesses all the functions of starting rheostats with the added improvement described.

### REFILL YOUR BURNED-OUT LAMPS.

The Pacific Incandescent Lamp Co. announces to the electric lighting trade, and to consumers of incandescent lamps in particular, that its new and splendidly equipped factory occupying the third floor of the Gutzkow Building, 933 Market street, San Francisco, has been working to full capacity for several months past, and that it is prepared to refill lamps or to supply refilled lamps in all voltages and candlepowers from stock.

Refilled lamps are as good as new ones in every way, and they are much cheaper. Write for prices, or better still, send in a trial lot of burned-out lamps to be refilled.

### A COMPOUND ENGINE WANTED.

On an advertising page of this issue appears an announcement that the Electric Improvement Company, San Jose, Cal., desires to receive propositions for the purchase of a good second-class, high-speed compound engine of a capacity ranging from 150 to 250 horsepower, as well as a 500-volt direct-current generator for the same. Parties having such apparatus (which must be in strictly first-class condition) for sale will find a ready purchaser in the company named.